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APPENDIX 1.0

VEDIC MATHS APPICATION IN DIFFERENT COMPETITIVE EXAMINATION

Table 21 showing different examinations in India where Vedic Maths can be applied

Name of the Entrance Exam	Details of the Exam	Related Courses/Career
JEE Mains and Advanced	Joint Engineering Entrance Examination	Engineering/ Architecture /Research and Development IIT/NIT/IIIT/CFTI
WB JEE	West Bengal Joint Engineering Entrance Examination	Engineering
K-CET	Karnataka Common Entrance Test	Engineering, Agriculture, Medicine
EAMCET	Engineering Agricultural and Medical Common Entrance Test	Engineer, Agriculture, Medicine
Rajasthan PET	Rajasthan Pre-Engineering Test	Engineering
MP PET	Madhya Pradesh Pre-Engineering Test	Engineering
J&K CET	Jammu and Kashmir Common Entrance Test	Engineering
Kerala CET	Kerala Common Entrance Test	Engineering
OJEE	Orissa Joint Engineering Entrance	Engineering
BITSAT	Birla Institute of Technology and Science Aptitude Test	Integrated 1st degree Engineering, Pharmacy and MSc Programs
DCE	Delhi College of Engineering	Engineering
BCECE	Bihar Combined Entrance Competitive Examination	Engineer, Agriculture, Medicine
AMU	Aligarh Muslim University	Engineering
NDA	National Defence Academy	Army, Navy, Airforce
CDS	Combined Defence Service	Army, Navy, Airforce
CAT	Common Admission Test	Post Graduate Programmes in Management

MAT	Management Aptitude Test	Post Graduate Programmes in Management
GATE	Graduate Aptitude Test Engineering	Post Graduate Programmes in Engineering
SSC	Staff Selection Commission	Lower Division Clerk / Junior Secretariat Assistant, Postal Assistant / Sorting Assistant & Data Entry Operator etc.
RRB	Railway Recruitment Board	Indian Railways
RBI	Reserve Bank of India	Bank Assistant, Grade B Officer
Income Tax	Income Tax Exam	IT Inspector, AO,PS Cadre posts
MT and AM exam	Management Trainees and Assistant Managers	Management Trainee, Assistant Manager
LIC/GIC (AAOs)	Life Insurance Corporation/ General Insurance Corporation Assistant Administrative Officer	Administrative Officer
CBI, Clerk	Central Bank of India, Clerk	Clerks
IBO, Clerk	Indian Overseas Bank, Clerk	Clerks
Canara Bank PO	Canara Bank Probationary Officers	Probationary Officers
Dena Bank Clerk	Dena Bank Probationary Officers	Probationary Officers
SBI	State Bank Probationary Officers	Probationary Officers
LDC	Lower Divisional Clerk	Lower Divisional Clerks
IDBI (officers)	Industrial Development Bank of India	Officers
NCERT CBSE (12)	The National Council of Educational Research and Training Central Board of Secondary Education	Any courses after 12
NCERT CBSE (10)	The National Council of Educational Research and Training Central Board of Secondary Education	Any courses after 10
NTSE	National Talent Search Exam	Scholarship

Examples of application of Vedic Maths in different competitive examinations

JEE Mains and Advanced - Joint Engineering Entrance Examination:

This exam is conducted after 10+2 education system. Candidates appearing for paper 1 answers 90 questions in 3 hours from Physics, Chemistry and Mathematics. Equal weightage is given to all three subjects. 4 marks for the correct response and 1 mark is deducted for wrong response. All questions are multiple answer type with one correct answer.

Example: Locus of the image of the point (2, 3) in the line (2x-3y+4)+k(x-2y+3)=0, k∈R, is a **(2015)**

(a) Straight line parallel to X-axis (b) Straight line parallel to Y-axis

(c) Circle of radius $\sqrt{2}$ (d) Circle of radius $\sqrt{3}$

Answer: 2x-3y=-4 $x = \frac{9-8}{-3-(-4)} = 1, \quad y = \frac{1+3}{2} = 2$

x-2y=-3 Find x and y then proceed to find the required locus.

Sutra Used: Urdhwa Tiryakbhyam (Vertically crosswise)

Examples from other engineering entrance examinations are given.

WB JEE (West Bengal Joint Engineering Entrance)

Example: $\int \frac{dx}{x(x+1)} =$ **(2009)**

(a) $log\ \left|\frac{x+1}{x}\right| + c$ (b) $log\ \left|\frac{x}{x+1}\right| + c$ (c)$log\ \left|\frac{x-1}{x}\right| + c$ (d) $log\ \left|\frac{x-1}{x+1}\right| + c$

Answer: $\int \frac{dx}{x(x+1)} = A\log x + B\log(x+1) + c = \log x - \log(x+1) + c$

Procedure: Consider $\frac{1}{x(x+1)} = \frac{A}{x} + \frac{B}{(x+1)}$

Put x= 0 to find A and put x+1= 0 to find B in $\frac{1}{x(x+1)}$. $A = \frac{1}{(0+1)}, B = \frac{1}{-1}$.

Sutra Used: Paravartya Yojayet (Transpose and Apply), Vilokanam (Mere Observation)

K-CET (Karnataka Common Entrance Test)

Example 1: $\int \frac{dx}{x^2+2x+2} =$ **(2004)**

(a) $\sin^{-1}(x+2) + c$ (b)$\sinh^{-1}(x+1) + c$

(c)$\tanh^{-1}(x+1) + c$ (d) $\tan^{-1}(x+1) + c$

Answer: (d) $\int \frac{dx}{x^2+2x+2} = \ = \frac{2}{\sqrt{|-4|}}\tan^{-1}\left(\frac{2x+2}{\sqrt{|-4|}}\right), a > 0, D < 0$

Procedure: Observe the sign of discriminant $D = b^2 - 4ac$ and a mentally.

$$Use\ I = \int \frac{dx}{ax^2 + bx + c} = \begin{cases} \frac{1}{\sqrt{D}} \log\left[\frac{f' - \sqrt{D}}{f' + \sqrt{D}}\right], & a > 0, D > 0 \\ \frac{1}{\sqrt{D}} \log\left[\frac{\sqrt{D} - f'}{\sqrt{D} + f'}\right], & a < 0, D > 0 \\ \frac{2}{\sqrt{|D|}} \tan^{-1}\left(\frac{f'}{\sqrt{|D|}}\right), & a > 0, D < 0 \\ \frac{2}{f'}, & D = 0 \end{cases}$$

Sutra Used: Chalana Kalanabhyam (Differential Calculus), Vilokanam (Mere Observation)

EAMCET

Example 1: The diameters of a circle are along 2x+y-7=0 and x+3y-11=0. Then, the equation of this circle, which also passes through (5, 7) is

(a) $x^2 + y^2 - 4x - 6y - 16 = 0$ (b) $x^2 + y^2 - 4x - 6y - 20 = 0$

(c) $x^2 + y^2 - 4x - 6y - 12 = 0$ (d) $x^2 + y^2 + 4x + 6y - 12 = 0$

Answer: 2x + y = 7

x + 3y =11 $x = \frac{1.11 - 7.3}{1.1 - 2.3} = \frac{-10}{-5} = 2$

Putting the value of x in 2x + y = 7 we get y = 3. Centre is (2, 3). Now (5, 7) lies on Option (c).

Sutra Used: Vilokanam (Mere Observation)

Example 2: $\int \frac{3}{2x^2 - x - 1} dx =$ **(1999)**

(a) $log\ \left(\frac{x-1}{x+1}\right) + c$ (b) $log\ \left(\frac{x+1}{2x+1}\right) + c$

(c) $log\ \left(\frac{x-1}{2x-1}\right) + c$ (d) $log\ \left(\frac{x-1}{2x+1}\right) + c$

Answer: (d) $\int \frac{3}{2x^2 - x - 1} dx = 3 \times \frac{1}{\sqrt{9}} \log\left[\frac{4x - 1 - \sqrt{9}}{4x - 1 + \sqrt{9}}\right],\ a > 0, D > 0$

Procedure: Observe the sign of discriminant $D = b^2 - 4ac$ and a mentally.

$$Use\ I = \int \frac{dx}{ax^2 + bx + c} = \begin{cases} \frac{1}{\sqrt{D}} \log\left[\frac{f' - \sqrt{D}}{f' + \sqrt{D}}\right], & a > 0, D > 0 \\ \frac{1}{\sqrt{D}} \log\left[\frac{\sqrt{D} - f'}{\sqrt{D} + f'}\right], & a < 0, D > 0 \\ \frac{2}{\sqrt{|D|}} \tan^{-1}\left(\frac{f'}{\sqrt{|D|}}\right), & a > 0, D < 0 \\ \frac{2}{f'}, & D = 0 \end{cases}$$

Sutra Used: Chalana Kalanabhyam (Differential Calculus), Vilokanam (Mere Observation)

Rajasthan PET

Example 1: $\int \frac{3x+2}{(x-2)^2(x-3)}dx =$ **(2008)**

(a) $11log\left(\frac{x-3}{x-2}\right)-\frac{8}{x-2}+c$ (b) $11log\left(\frac{x+3}{x+2}\right)-\frac{8}{x-2}+c$

(c)$11log\left(\frac{x-3}{x-2}\right)+\frac{8}{x-2}+c$ (d) $11log\left(\frac{x+3}{x+2}\right)+\frac{8}{x-2}+c$

Answer: $(c)\int \frac{3x+2}{(x-2)^2(x-3)}dx = A\left(\frac{-1}{x-2}\right)+B\log(x-2)+C\log(x-3)$

$$= 11log\left(\frac{x-3}{x-2}\right)+\frac{8}{x-2}+c$$

Procedure: Consider $\frac{3x+2}{(x-2)^2(x-3)}=\frac{A}{(x-2)^2}+\frac{B}{(x-2)}+\frac{C}{(x-3)}$

Put x-2=0 to find A and put x-3= 0 to find C in $\frac{3x+2}{(x-2)^2(x-3)}$.

$A=\frac{3(2)+2}{(2-3)}=-8, C=\frac{3(3)+2}{(3-2)^2}=11$. Option (c) correct answer by observation.

Sutra Used: Paravartya Yojayet (Transpose and Apply), Vilokanam (Mere Observation)

MP PET

Example 1: $\int \frac{e^x}{(2+e^x)(e^x+1)}dx =$ **(2005)**

(a) $log\left(\frac{e^x+1}{e^x+2}\right)+c$ (b) $log\left(\frac{e^x+2}{e^x+1}\right)+c+c$

(c)$\left(\frac{e^x+1}{e^x+2}\right)+c$ (d) $\left(\frac{e^x+2}{e^x+1}\right)+c$

Answer:$(c)\ \int \frac{e^x}{(2+e^x)(e^x+1)}dx =$ A $\log(2+e^x)+B\ log(e^x+1))+c$

$$= -\log(2+e^x)+1\ log(e^x+1))+c$$

Procedure: Consider $\frac{1}{(2+t)(t+1)}=\frac{A}{(2+t)}+\frac{B}{(t+1)}$ (Taking $e^x=t$ and $e^x dx=dt$)

Put t= -2 to find A and put t= -1 to find B in $\frac{1}{(2+t)(t+1)}$. $A=\frac{1}{(-2+1)}, B=\frac{1}{(2-1)}$.

Sutra Used: Paravartya Yojayet (Transpose and Apply), Vilokanam (Mere Observation)

Example 2: $\int_2^3 \frac{x+1}{x^2(x-1)}dx$ **(2004)**

(a) $log\left(\frac{16}{9}\right)+\frac{1}{6}$ (b) $log\left(\frac{16}{9}\right)-\frac{1}{6}$

(c)$2log\ (2)-\frac{1}{6}$ (d) $log\left(\frac{4}{3}\right)-\frac{1}{6}$

Answer: Let $\frac{x+1}{x^2(x-1)}=\frac{A}{x}+\frac{B}{x^2}+\frac{C}{x-1}$ Put x=1 and x=0 in $\frac{x+1}{x^2(x-1)}$ to find C and B.

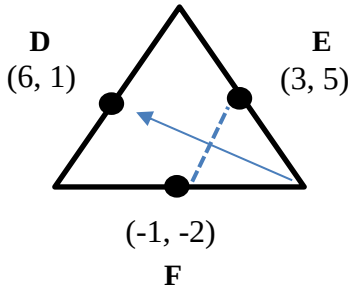
$C = \frac{1+1}{1} = 2,\ B = \frac{0+1}{0-1} = -1$ Integrate $\int_2^3 \frac{2}{x-1}dx = 2log\ (2)$ present in (c).

J&K CET

Example: The midpoints of a triangle are D(6,1), E(3,5) and F(-1,-2), then the vertex opposite to D is **(2007)**

(a)(-4, 2) (b) (-4, 5) (c)(2,5) (d)(10,8)

Answer:



Vertex opposite to D is

[(3+(-1)-6), (5+(-2)-1)]=[-4, 2]

Procedure: (F+E-D) Sutra Used: Urdhwa Tiryakbhyam (Vertically crosswise)

Kerala CET **(2010)**

Example: $\int \frac{x+2}{2x^2+6x+5}dx = p\int \frac{4x+6}{2x^2+6x+5}dx + \frac{1}{2}\int \frac{dx}{2x^2+6x+5}$ then the value of p is

(a) $\frac{1}{3}$ (b) $\frac{1}{2}$ (c) $\frac{1}{4}$ (d) 2

Answer: $p = \frac{1}{2}$

Procedure: If $I = \int \frac{Ax+B}{ax^2+bx+c}dx$ then $Numerator = p\frac{d(denominator)}{dx} + q$

Here $p = \frac{A}{2a}$ Sutra Used: Vilokanam (Mere Observation)

OJEE (Orissa Joint Engineering Entrance)

Example 1: $\int \frac{x}{(x^2-a^2)(x^2-b^2)}dx =$ **(2007)**

(a) $\frac{1}{a^2-b^2}\log\left|\frac{x^2-a^2}{x^2-b^2}\right| + c$ (b) $\frac{1}{a^2-b^2}\log\left|\frac{x^2-b^2}{x^2-a^2}\right| + c$

(c) $\frac{1}{2(a^2-b^2)}\log\left|\frac{x^2-a^2}{x^2-b^2}\right| + c$ (d) $\frac{1}{2(a^2-b^2)}\log\left|\frac{x^2-b^2}{x^2-a^2}\right| + c$

Answer: $\int \frac{x}{(x^2-a^2)(x^2-b^2)}dx = \int \frac{1}{2}\left[\frac{dt}{(t-a^2)(t-b^2)}\right]$ (Put $x^2 = t, 2xdx = dt$)

$= \int \frac{1}{2}\left[\frac{A}{(t-a^2)} + \frac{B}{(t-b^2)}\right]dt = \frac{1}{2}\int \left[\frac{1/(a^2-b^2)}{(t-a^2)} + \frac{1/(b^2-a^2)}{(t-b^2)}\right]dt =$

$\frac{1}{2(a^2-b^2)}\log\left|\frac{x^2-a^2}{x^2-b^2}\right| + c$

Procedure: Put $t = a^2$ to find A and $t = b^2$ to find B in $\frac{1}{(t-a^2)(t-b^2)}$

Therefore $A = \frac{1}{(a^2-b^2)}, B = \frac{1}{(b^2-a^2)}$

Sutra Used: Paravartya Yojayet (Transpose and Apply), Vilokanam (Mere Observation)

Example 2: $\int \frac{x+1}{x(1+xe^x)^2}dx =$ **(2009)**

(a)$\log\left|\frac{xe^x}{1+xe^x}\right| + \frac{1}{1+xe^x} + c$ (b) $\log\left|\frac{xe^x}{1+xe^x}\right| - \frac{1}{1+xe^x} + c$

(c) $\log\left|\frac{1+xe^x}{xe^x}\right| + \frac{1}{1+xe^x} + c$ (d) $None$

BITSAT

Example: $\int \frac{dx}{x^4+x^3} = \frac{A}{x^2} + \frac{B}{x} + \log\left|\frac{x}{x+1}\right| + c$ then **(2009)**

(a)$A = \frac{1}{2}, B = 1$ (b) $A = 1,\ B = \frac{-1}{2}$ (c) $A = \frac{-1}{2}, B = 1$ (d) $A = 1, B = 1$

$\frac{1}{x^4+x^3} = \frac{1}{x^3(x+1)} = \frac{A}{x^3} + \frac{B}{x^2} + \frac{C}{x} + \frac{D}{x+1}$

$Put\ x = 0\ in\ \frac{1}{x^3(x+1)}\ to\ get\ A = \frac{1}{0+1} = 1$

$Put\ x = -1\ in\ \frac{1}{x^3(x+1)}\ to\ get\ C = \frac{1}{(-1)^3} = -1$

DCE

Example 1: Area of quadrilateral whose vertices are (2,3), (3,4), (4,5) and (5,6) is equal to **(2003)**

(a)0 (b)4 (c)6 (d)None

Ans: $A = \frac{1}{2}\begin{vmatrix} 2 & 3 \\ 3 & 4 \\ 4 & 5 \\ 5 & 6 \\ 2 & 3 \end{vmatrix} = (8-9) + (15-16) + (24-25) + (15-12) = -1-1-1+3 = 0$

Sutra Used: Urdhwa Tiryakbhyam (Vertically crosswise)

Example 2: $\int \frac{dx}{x^2+4x+13}dx =$ **(2007)**

(a) $log\ (x^2+4x+13) + c$ (b) $\frac{1}{3}\tan^{-1}\left|\frac{x+2}{3}\right| + c$

(c)$log\ (2x+4) + c$ (d)$\frac{2x+4}{(x^2+4x+13)^2} + c$

Answer: $\frac{2}{\sqrt{|-36|}}\tan^{-1}\left(\frac{2x+4}{\sqrt{|-36|}}\right), a > 0, D < 0$

Procedure: $I = \int \frac{dx}{ax^2+bx+c} = \begin{cases} \frac{1}{\sqrt{D}} \log\left[\frac{f'-\sqrt{D}}{f'+\sqrt{D}}\right], & a>0, D>0 \\ \frac{1}{\sqrt{D}} \log\left[\frac{\sqrt{D}-f'}{\sqrt{D}+f'}\right], & a<0, D>0 \\ \frac{2}{\sqrt{\lvert D\rvert}} \tan^{-1}\left(\frac{f'}{\sqrt{\lvert D\rvert}}\right), & a>0, D<0 \\ \frac{2}{f'}, & D=0 \end{cases}$

Sutra Used: Chalana Kalanabhyam (Differential Calculus), Vilokanam (Mere Observation)

BCECE **(2010)**

Example: $\int \frac{dx}{\sqrt{(1-x)(x-2)}} dx =$

(a) $\sin^{-1}(2x-3)+c$ (b) $\sin^{-1}(2x+5)+c$

(c)$\sin^{-1}(3-2x)+c$ (d) $\sin^{-1}(5-2x)+c$

Ans: $\int \frac{dx}{\sqrt{(1-x)(x-2)}} dx = \int \frac{dx}{\sqrt{-x^2+3x-2}} dx = \frac{1}{\sqrt{\lvert-1\rvert}} \sin^{-1}\left[\frac{\lvert-2x+3\rvert}{\sqrt{1}}\right] + c$

Procedure: $I = \int \frac{dx}{\sqrt{ax^2+bx+c}} = \begin{cases} \frac{1}{\sqrt{a}} \log\left[\frac{f'}{2a} + \sqrt{\frac{f}{a}}\right], a>0, D>0 \\ \frac{1}{\sqrt{\lvert a\rvert}} \sin^{-1}\left[\frac{\lvert f'\rvert}{\sqrt{D}}\right], a<0, D>0 \\ \frac{1}{\sqrt{a}} \sinh^{-1}\left[\frac{f'}{\sqrt{D}}\right], a>0, D<0 \end{cases}$

Sutra Used: Chalana Kalanabhyam (Differential Calculus), Vilokanam (Mere Observation)

AMU **(2007)**

Example: $\int \frac{2x^2+3}{(x^2-1)(x^2+4)} dx = a log\left(\frac{x-1}{x+1}\right) + b \tan^{-1}\left(\frac{x}{2}\right) + c$ then value of a and b are

(a)(1,-1) (b)(-1, 1) (c)$\left(\frac{1}{2}, \frac{-1}{2}\right)$ (d) $\left(\frac{1}{2}, \frac{1}{2}\right)$

Procedure: Consider $\frac{2x^2+3}{(x^2-1)(x^2+4)} = \frac{2t+3}{(t-1)(t+4)} = \frac{A}{(t-1)} + \frac{B}{(t+4)}$,

Put $t=1$ and $t=-4$ in $\frac{2t+3}{(t-1)(t+4)}$ to find $A = \frac{2.1+3}{1+4} = 1, B = \frac{2.(-4)+3}{-4-1} = 1$

$\int \frac{2x^2+3}{(x^2-1)(x^2+4)} dx = \int \frac{1}{(x^2-1)} dx + \int \frac{1}{(x^2+4)} dx = \frac{1}{2} log\left(\frac{x-1}{x+1}\right) + \frac{1}{2} \tan^{-1}\left(\frac{x}{2}\right) + c$

Sutra Used: Paravartya Yojayet (Transpose and Apply), Vilokanam (Mere Observation)

NDA

Example 1: Two straight lines $x-3y-2=0$ and $2x-6y-6=0$ **(2011 -I)**

(a)Never intersect (b) Intersect at a single point

(c) Intersect at infinite number of points (d) Intersect at more than one point (finite)

Answer: By observation (Vilokanam) we can say slopes are same. Therefore lines are parallel and intersect at infinite number of points.

Example 2: The point of intersection of two lines $2x + 3y + 4 = 0$ and $4x + 3y + 2 = 0$ is at a distance d from origin. The value of d is **(2009 -I)**

(a)$\sqrt{2}$ (b) $\sqrt{3}$ (c) $\sqrt{5}$ (d) $\sqrt{7}$

Other interesting applications are taken from different Vedic Maths books published.

Application 1: (Sopantyadwayamantyam) The Ultimate and twice the penultimate:

This sutra is used under special conditions.

$If\ \frac{1}{AB} + \frac{1}{AC} = \frac{1}{AD} + \frac{1}{BC}$, and A,B,C,D are algebraic terms in A.P. then D+2C=0 is one solution.

Example: Find atleast one solution of the equation:

$$\frac{1}{x^2+5x+6} + \frac{1}{x^2+6x+8} = \frac{1}{x^2+7x+10} + \frac{1}{x^2+7x+12}$$

$$\Rightarrow \frac{1}{(x+2)(x+3)} + \frac{1}{(x+2)(x+4)} = \frac{1}{(x+2)(x+5)} + \frac{1}{(x+3)(x+4)}$$

$$\Rightarrow x + 5 + 2(x + 4) = 0 \ \Rightarrow 3x = -13 \Rightarrow x = \frac{-13}{3}$$

Application 2: (Sunyam Samyasamuccya) If the Samyasamuccya is same then it is zero

Example: If $\frac{1}{3x-2} + \frac{1}{2x-1} = 0\ Find\ x.$

$Ans: If\ the\ numerators\ are\ same\ then\ sum\ of\ the\ denominators = 0$

$5x - 3 = 0 \Rightarrow x = \frac{3}{5}$

Application 3: (Anurupya Sunyamanyat) If one is the ratio the other is zero

Example: solve $3x + 7y = 2$

$$4x + 21y = 6$$

Ans: Observe that y-coefficients are in the ratio 7:21 or 1:3 which is same as the ratio of independent terms which is 2:6. Hence the other variable x=0 and 7y=2 or y=$\frac{2}{7}$

Application 4: (Paravartya) Tranpose and apply

Resolve into Partial Fractions

$$\frac{x^2+1}{(x-1)(x-2)(x-3)} = \frac{A}{(x-1)} + \frac{B}{(x-2)} + \frac{C}{(x-3)}$$

Put x=1 in the expression (LHS). A=1

Put x=2 in the expression. B=-5

Put x=3 in the expression. C=5

$$\frac{x^2+1}{(x-1)(x-2)(x-3)} == \frac{1}{(x-1)} - \frac{5}{(x-2)} + \frac{5}{(x-3)}$$

Other important applications discussed in VM books

Arithmetical applications

- Squaring the numbers

  $34^2 = 09/24/16 = 1156$

- Cubing the numbers

  $34^3 = 27/108/144/64 = 39304$

- Square root of numbers

  Find the square root of 70.

  Ans: The nearest lowest square closer to 70 is 64. The square root of 64 is 8.Now divide 70 by 8. We get 8.75.

  Now take the average of 8 and 8.75.

  So $\sqrt{70} = \frac{8+8.75}{2} = \frac{16.75}{2} = 8.37$

- Cube root of perfect cube numbers

  Find the cube root of 54872

  Ans: Divide the number into two parts. The last three digits into 1 part and rest into another part. i.e. 54/872

  Consider the last part 872. It ends with digit 2. So the unit digit in the cube root will be 8.

  Consider the 1st part 54. It lies between the perfect cubes, 27 and 64. Take the smaller cube root which is 3. So, $\sqrt[3]{54872} = 38$

- Fractions

  $\frac{2}{5}+\frac{3}{7}=\frac{2\times7+3\times5}{5\times7}=\frac{29}{35}$

Algebraic applications

- Quadratic equation

  Solve $\frac{x}{x+4}+\frac{x+4}{x}=\frac{122}{11}$

  $\frac{x}{x+4}+\frac{x+4}{x}=11+\frac{1}{11}\Rightarrow\frac{x}{x+4}=11\ or\ \frac{x+4}{x}=\frac{1}{11}$

  $\Rightarrow x=\frac{-22}{5}\ or\ \frac{2}{5}$

- Cubic equation

  $x^3+6x^2+11x+6=0$

  $\therefore x^3+6x^2=-11x-6$

  But $(x+2)^3=x^3+6x^2+12x+8$

  $\therefore (x+2)^3=-11x-6+12x+8=x+2$

  $put\ y=(x+2)\Rightarrow y^3=y$

  $\therefore y=0\ or\ \pm1\ \Rightarrow x=-2,-3\ or-1.$

- Biquadratic equations

  $solve\ x^4+8x^3+14x^2-8x-15=0$

  $\Rightarrow x^4+8x^3=-14x^2+8x+15=0$

  $\Rightarrow (x+2)^4=x^4+8x^3+24x^2+32x+16$

  $\Rightarrow (x+2)^4=10(x+2)^2-9$

  $\Rightarrow y^4=10y^2-9\ \Rightarrow y=\pm1\ or\ \pm3$

  $\Rightarrow x=-1\ or-3\ or\ 1\ or-5$

- Highest Common Factor

  Find H.C.F. of $x^2+6x+5\ and\ x^2+4x-5$

  Sub Sutras used: Lopana Sthapana, Sankalana – Vyavakalanam, Adyam Adyena.

  Subtraction method:

Ans: $x^2 + 6x + 5$

$x^2 + 4x - 5$

(-) (-) (+)

2x+10 Equating this to zero we get H.C.F. = x+5

- **Simultaneous simple equations**

  Sutra used: vertically and crosswise

  Find values of x and y if 3x+5y=13 and 4x+7y=18

  3x + 5y = 13 ax+by=c

  4x + 7y = 18 dx+ey=f

  x = $\frac{5.18-13.7}{5.4-7.3} = 1$, y = $\frac{13.4-18.3}{5.4-7.3} = -2$, x = $\frac{bf-ce}{bd-ae}$, y = $\frac{cd-af}{bd-ae}$

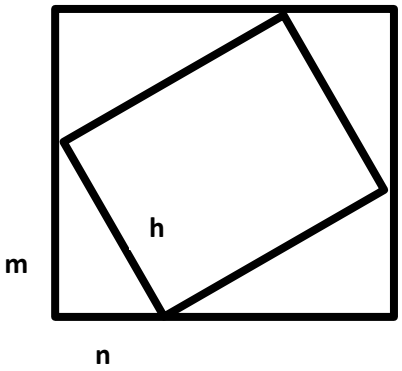
- **Integration by partial fractions**

  $\int \frac{\mathbf{1}}{(x+2)(x+3)} = \int \frac{A}{(x+2)} + \int \frac{B}{(x+3)} = \boldsymbol{log}\,(x+2) - \boldsymbol{log}\,(x+3)$

  Here directly we can write A= 1 and B=-1 by making terms x+2=0 and x+3=0. Then we can integrate.

Geometry

- Pythagoras theorem



$h^2 + 4\left(\frac{1}{2}mn\right) = (m+n)^2$

$h^2 = m^2 + n^2$

- Analytical Geometry

  Find the equation of the line passing through (9,17) and (7, -2).

  Ans: (17-(-2))x+(9-7)y=constant

  Or 19x+2y=137 (by substituting any one of the points in equation)

Quadratic Equation: quadratic forms always have derivatives and discriminants as in, $f(x) = ax^2 + bx + c$, with derivative $f'(x) = 2ax + b$ and discriminant, $D = b^2 - 4ac$.

The Vedic method derives the first differential of each term by multiplying its Ghata (the exponent) by the Anka (its coefficient) and reducing power of x by one. A second observation is that $2ax + b = \pm\sqrt{b^2 - 4ac}$ i.e. $f' = \pm\sqrt{D}$ (the derivative of a quadratic form is equal to the square root of the discriminant) [4]. These two observations allow us to express results concerning integrals by replacing $2ax + b$ by f', and $b^2 - 4ac$ by D, as demonstrated in the worked examples below. Both derivative and discriminant can be calculated mentally without using pen and paper, and the final answer obtained directly by referring to these results.

Simplified versions of four different types of quadratic integral are presented below. The number of steps using the conventional method and the Vedic short cut method are compared in Table 1. Comparative lengths of calculations are illustrated in Table 2.

Type 1:

$$I_1 = \int \frac{dx}{ax^2 + bx + c} = \begin{cases} \frac{1}{\sqrt{D}} \log\left[\frac{f' - \sqrt{D}}{f' + \sqrt{D}}\right], & a > 0, D > 0 \\ \frac{1}{\sqrt{D}} \log\left[\frac{\sqrt{D} - f'}{\sqrt{D} + f'}\right], & a < 0, D > 0 \\ \frac{2}{\sqrt{|D|}} \tan^{-1}\left(\frac{f'}{\sqrt{|D|}}\right), & a > 0, D < 0 \\ \frac{2}{f'}, & D = 0 \end{cases} \quad (1)$$

Type 2:

$$I_2 = \int \frac{dx}{\sqrt{ax^2 + bx + c}} = \begin{cases} \frac{1}{\sqrt{a}} \log\left[\frac{f'}{2a} + \sqrt{\frac{f}{a}}\right], & a > 0, D > 0 \\ \frac{1}{\sqrt{|a|}} \sin^{-1}\left[\frac{|f'|}{\sqrt{D}}\right], & a < 0, D > 0 \\ \frac{1}{\sqrt{a}} \sinh^{-1}\left[\frac{f'}{\sqrt{D}}\right], & a > 0, D < 0 \end{cases} \quad (2)$$

Type 3:

$$I_3 = \int \frac{px + q}{ax^2 + bx + c} dx = l.\log f + m.I_1, \quad (3)$$

where $l = \frac{p}{2a}, m = q - lb$

Type 4:

$$I_4 = \int \frac{px + q}{\sqrt{ax^2 + bx + c}} dx = l.2\sqrt{f} + m.I_2, \quad (4)$$

where $l = \frac{p}{2a}, m = q - lb$

Table 1: Conventional and Short Cut Methods

Comparison of Number of Steps

Conventional Method	Short Cut Method
1. Write the quadratic equation in complete square format **2.** Recognize the sign of coefficient of x^2 and sign of a^2 **3.** Use the standard result to get the final answer	**1.** Recognize the sign of coefficient of x^2 and sign of Discriminant. **2.** Use the standard result to get the final answer.

Table 2: Illustrative Calculations for the Six Types of Quadratic Integrals: Table compares Conventional and Short cut methods with 6 illustrations. Mental calculations needed for the shortcut method are shown in the third column.

Type 1 - Illustration:

1. $\int \frac{dx}{9x^2-12x+8} =$

(a) $\frac{1}{6}\tan^{-1}\frac{3x+2}{2}$ (b) $\frac{1}{6}\log\frac{3x-2}{3x+2}$ (c) $\frac{1}{6}\sin^{-1}\frac{3x+2}{2}$ (d) $\frac{1}{6}\tan^{-1}\frac{3x-2}{2}$

Conventional Maths solution	***Short cut solution***	***Mental calculation***
$\int \frac{dx}{9x^2-12x+8}$ $=\int \frac{dx}{9\{x^2-\frac{12}{9}x+\frac{8}{9}\}}$ $=\frac{1}{9}\int \frac{dx}{\{x^2-\frac{4}{3}x+\frac{8}{9}\}}$ $=\frac{1}{9}\int \frac{dx}{\{x^2-2\left(\frac{2}{3}\right)x+\frac{4}{9}-\frac{4}{9}+\frac{8}{9}\}}$ $=\frac{1}{9}\int \frac{dx}{\left(x-\frac{2}{3}\right)^2+\left(\frac{2}{3}\right)^2}$ $=\frac{1}{9}\frac{1}{\left(\frac{2}{3}\right)}\tan^{-1}\frac{x-\frac{2}{3}}{\frac{2}{3}}$ $=\frac{1}{6}\tan^{-1}\frac{3x-2}{2}$	$\int \frac{dx}{9x^2-12x+8}$ $=\frac{2}{\sqrt{144}}\tan^{-1}\frac{18x-12}{12}$ $=\frac{1}{6}\tan^{-1}\frac{3x-2}{2}$	Calculate $D = 144 - 288$ $= -144 < 0$ Recognize sign of a $a = 9 > 0$ $f' = 18x - 12$

Type 2 - Illustration:

2. $\int \frac{dx}{\sqrt{1-4x-2x^2}} =$

(a) $\frac{1}{\sqrt{2}}\sin^{-1}(\frac{\sqrt{3}}{\sqrt{2}}(2x+1))$ (b) $\frac{1}{\sqrt{2}}\sin^{-1}(\frac{\sqrt{2}}{\sqrt{3}}(2x+1))$

(c) $\frac{1}{\sqrt{2}}\sin^{-1}(\frac{\sqrt{3}}{\sqrt{2}}(x+1))$ (d) $\frac{1}{\sqrt{2}}\sin^{-1}(\frac{\sqrt{2}}{\sqrt{3}}(x+1))$

Conventional Maths solution	***Short cut solution***	***Mental calculation***
$\int \frac{dx}{\sqrt{1-4x-2x^2}}$	$\int \frac{dx}{\sqrt{1-4x-2x^2}}$	Calculate
$= \int \frac{dx}{\sqrt{-2\left(x^2+2x-\frac{1}{2}\right)}}$	$= \frac{1}{\sqrt{2}}\sin^{-1}\frac{4x+4}{\sqrt{24}} + c$	$D = 16 - 4(-2)(1)$
$= \int \frac{dx}{\sqrt{-2\left(x^2+2x+1-\frac{1}{2}-1\right)}}$	$= \frac{1}{\sqrt{2}}\sin^{-1}(\frac{\sqrt{2}}{\sqrt{3}}(x+1)) + c$	$= 24 > 0$
$= \int \frac{dx}{\sqrt{-2\left((x+1)^2-\frac{3}{2}\right)}}$		Recognize sign of $a = -2 < 0$
$= \int \frac{dx}{\sqrt{2\left(\frac{3}{2}-(x+1)^2\right)}}$		$f' = -4x - 4$
$= \int \frac{dx}{\sqrt{2}\sqrt{\left(\left(\frac{\sqrt{3}}{2}\right)^2-(x+1)^2\right)}}$		
$= \frac{1}{\sqrt{2}}\sin^{-1}\frac{x+1}{\frac{\sqrt{3}}{\sqrt{2}}} + \boldsymbol{c}$		
$= \frac{1}{\sqrt{2}}\sin^{-1}(\frac{\sqrt{2}}{\sqrt{3}}(x+1)) + \boldsymbol{c}$		

Type 3 - Illustration:

3. $I = \int \frac{3x+1}{2x^2-2x+3}dx =$

(a) $I = \frac{3}{4}\log(2x^2 - 2x + 3) + \frac{\sqrt{5}}{2}\tan^{-1}\left(\frac{2x-1}{\sqrt{5}}\right) + c$ (b) $I = \frac{3}{4}\log(2x^2 - 2x + 3) + \frac{\sqrt{5}}{4}\tan^{-1}\left(\frac{-2x-1}{\sqrt{5}}\right) + c$

(c) $I = \frac{3}{4}(2x^2 - 2x\ + 3) + \frac{\sqrt{5}}{2}\tan^{-1}\left(\frac{2x-1}{\sqrt{5}}\right) + c$ (d) $I = \frac{3}{4}log(2x^2 - 2x\ + 3) + \frac{\sqrt{5}}{2}\tan^{-1}\left(\frac{2x-4}{\sqrt{5}}\right) + c$

Conventional Maths solution	***Short cut solution***	***Mental calculation***
$I = \int \frac{3x+1}{2x^2-2x+3}dx$ Let $3x + 1 = l(4x - 2) + m$ $\Rightarrow 4l = 3 \Rightarrow l = \frac{3}{4}$, $-2l + m = 1$ $\Rightarrow m = 1 + \frac{3}{2} = \frac{5}{2}$ $Now\ I = \int \frac{\frac{3}{4}(4x-2)+\frac{5}{2}}{2x^2-2x+3}dx$ $I = \frac{3}{4}\int \frac{(4x-2)}{2x^2-2x+3}dx\ + \frac{5}{2}\int \frac{(4x-2)}{2x^2-2x+3}dx$ $= \frac{3}{4}\log(2x^2 - 2x\ +\ 3) + \frac{5}{2}I_1$ Consider $2x^2 - 2x\ +\ 3 = 2\left(x^2 - x\ + \frac{3}{2}\right)$ $= 2\left(x^2 - 2.\frac{1}{2}x\ + \frac{1}{4} + \frac{3}{2} - \frac{1}{4}\right)$ $= 2\left[\left(x - \frac{1}{2}\right)^2 + \frac{5}{4}\right]$ Now $I_1 = \frac{1}{2}\int \frac{dx}{\left[\left(x-\frac{1}{2}\right)^2+\left(\frac{\sqrt{5}}{2}\right)^2\right]}$ $= \frac{1}{\sqrt{5}}\tan^{-1}\left(\frac{2x-1}{\sqrt{5}}\right) + c$ $\therefore I = \frac{3}{4}\log(2x^2 - 2x\ +\ 3) +$ $\frac{5}{2}\frac{1}{\sqrt{5}}\tan^{-1}\left(\frac{2x-1}{\sqrt{5}}\right) + c$	$I = \int \frac{3x+1}{2x^2-2x+3}dx$ $l = \frac{3}{4}, m = 1 - \frac{3}{4}(-2) = \frac{5}{2}$ $\therefore I = \frac{3}{4}\log(2x^2 - 2x\ +$ $3) +$ $\frac{\sqrt{5}}{2}\frac{2}{\sqrt{20}}\tan^{-1}\left(\frac{4x-2}{\sqrt{20}}\right) + c$ $\therefore I = \frac{3}{4}\log(2x^2 - 2x\ +$ $3) + \frac{\sqrt{5}}{2}\tan^{-1}\left(\frac{2x-1}{\sqrt{5}}\right) + c$	Calculate $D = 4 -$ $4(2)(3) =$ $-20 < 0$ Recognize sign of $a = 2 > 0$ $f' = 4x - 2$

Type 4 - Illustration:

4. $\boldsymbol{I = \int \frac{3x+7}{\sqrt{1-x-x^2}}dx}$

(a) $I = -\sqrt{1-x-x^2} + \frac{11}{2}\sin^{-1}\left(\frac{2x+1}{\sqrt{5}}\right) + c$

(b) $I = -\sqrt{1-x-x^2} + \frac{11}{2}\sin^{-1}\left(\frac{x+1}{\sqrt{5}}\right) + c$

(c) $I = -3\sqrt{1-x-x^2} + \frac{11}{2}\sin^{-1}\left(\frac{2x+1}{\sqrt{5}}\right) + c$

(d) $I = -3\sqrt{1-x-x^2} + \frac{1}{2}\sin^{-1}\left(\frac{2x+1}{\sqrt{5}}\right) + c$

Conventional Maths solution	***Short cut solution***	***Mental calculation***
$I = \int \frac{3x+7}{\sqrt{1-x-x^2}}dx$ Let $3x + 7 = l\frac{d}{dx}(1-x-x^2) + m$ $\Rightarrow -2l = 3 \Rightarrow l = \frac{-3}{2}, -l + m = 7 \Rightarrow m = \frac{11}{2}$ $I = \int \frac{\frac{-3}{2}(-1-2x)+\frac{11}{2}}{\sqrt{1-x-x^2}}dx$ $\Rightarrow I = \int \frac{\frac{-3}{2}(-1-2x)}{\sqrt{1-x-x^2}}dx + \frac{11}{2}\int \frac{dx}{\sqrt{1-x-x^2}}$ Consider $1 - x - x^2 = -(x^2 + x - 1)$ $= -(x^2 + 2.\frac{1}{2}.x + \frac{1}{4} - \frac{1}{4} - 1)$ $= -\left[\left(x+\frac{1}{2}\right)^2 - \frac{5}{4}\right]$ $= \left[\left(\frac{\sqrt{5}}{2}\right)^2 - \left(x+\frac{1}{2}\right)^2\right]$ $\therefore I' = \int \frac{dx}{\sqrt{\left(\frac{\sqrt{5}}{2}\right)^2 - \left(x+\frac{1}{2}\right)^2}} = \sin^{-1}\left(\frac{2x+1}{\sqrt{5}}\right)$ $\therefore I = -3\sqrt{1-x-x^2} + \frac{11}{2}\sin^{-1}\left(\frac{2x+1}{\sqrt{5}}\right) + c$	$I = \int \frac{3x+7}{\sqrt{1-x-x^2}}dx$ $l = -\frac{3}{2}$, $m = 7—\frac{3}{2}(-1) = \frac{11}{2}$ $\therefore I = -\frac{3}{2}2\sqrt{1-x-x^2} + \frac{11}{2}.\frac{1}{\sqrt{1}}\sin^{-1}\left(\frac{\lvert-2x-1\rvert}{\sqrt{5}}\right) + c$ $\therefore I = -3\sqrt{1-x-x^2} + \frac{11}{2}\sin^{-1}\left(\frac{2x+1}{\sqrt{5}}\right) + c$	Calculate $D = (-1)^2 - 4(-1)(1) = 1 + 4 = 5 > 0$ Recognize sign of $a = -1 < 0$ $f' = -2x - 1$

APPENDIX 2.0

INFORMED CONSENT FORMS: A SAMPLE COPY

2.1 Principal Informed Consent

Swami Vivekananda Yogā Anusandhana Samsthana, Bangalore

Study title: Evaluation of yogic breathing and Vedic Maths module in the management of Math Anxiety, working memory, math-aptitude, and math performance in School children

Principal Investigator: Vasant V Shastri, Ph.D. Scholar, (Yogā and Education)

Division of Yogā and Management, SVYASA, Bangalore. (Contact Number: +919986415625)

Faculty Adviser: Dr. Sanjeev Patra, **Assistant Professor,**

Division of Yogā and Life Sciences, SVYASA, Bangalore. (Contact Number: +919483390476)

This form is designed to provide you with information about this study. The Principle investigator or representative will describe this study to you and answer any of questions. If you have any questions or complaints about the informed consent process or the research study, please contact the Principal Investigator.

This study is to evaluate the Yogic breathing practices (Kapālabhāti, Nāḍī Śuddhi, Bhrāmarī) and Vedic Maths modules (Easy problem solving skills), in the management of Math Anxiety, working memory, math performance in school going children. Students will participate in six days workshop on Yogic breathing Practices and Vedic Maths. In the unlikely event of student sustaining a physical or psychological injury arising out of this study, primary health care will be provided.

Assessments consist of cognitive tests and questionnaires which will be conducted through computer and paper pencil tasks. No potential risks are anticipated by undergoing these tests. No other sensitive information is collected. All information obtained in this study is strictly confidential unless disclosure is required by law.

No incentives will be provided for participants. However, if you wish results of test scores will be sent to you through e-mail. Students are free to express any discomfort or problem during workshop or test session to the administrator. Students are free to withdraw their participation at any point of the study without penalty after informing the Principal Investigator.

Principal Investigator

I agree that I have read this informed consent fully. I fully understand the contents of this document and am openly willing to send students (9 yrs – 16 yrs) to take part in this study.
All the queries related to participation of students were clarified to me and in case of any problem or further clarification I may contact the above mentioned persons.

Date:
Place:

Head of the Institution

2.2 Guardian Informed Consent

Swami Vivekananda Yogā Anusandhana Samsthana, Bangalore

Study title: Evaluation of yogic breathing and Vedic Maths module in the management of Math Anxiety and cognitive skills in School children

Principal Investigator: Vasant V Shastri, Ph.D. Scholar, Division of Yogā and Physical Sciences, SVYASA, Bangalore. (Contact Number: +919986415625)

Faculty Adviser: Dr. Sanjeev Patra, **Assistant Professor,** Division of Yogā and Life Sciences, SVYASA, Bangalore. (Contact Number: +919483390476)

Mathematics learning and cognitive skills development are two major issues in the life of every school going child. Good performance in mathematics may fetch better career options later. Similarly, certain cognitive skills interlinked with mathematics learning also have equal importance in deciding career. But students who are math-anxious have a strong tendency to avoid math, which ultimately undercuts their math competence and forecloses important career paths.

One possible way to make maths interesting is learning Vedic Maths that reduces the cumbersome-looking calculations in conventional mathematics to a very simple one by suggesting easy one line method. Another way to strengthen or to develop cognitive skills may be practicing yogic breathing technique (*prāṇayāma*).

So this study is to evaluate the Yogic breathing practices (Kapālabhāti, Nāḍī Śuddhi, Bhrāmarī) and Vedic Maths modules (Easy problem solving skills), in the management of Math Anxiety and cognitive skills in school going children.

Student will participate in 15 days free workshop on Yogic breathing Practices (Prāṇāyāma) and Vedic Maths (Speed maths). Assessments consist of cognitive tests

and questionnaires which will be conducted through computer and paper pencil tasks. No potential risks are anticipated by undergoing these tests. No other sensitive information is collected. All information obtained in this study is strictly confidential unless disclosure is required by law. The analysis or interpretation will not be viable for medical or legal purposes. In the unlikely event of student sustaining an injury arising out of this study, primary health care will be provided.

No incentives will be provided for participants. Students are free to express any discomfort or problem during workshop or test session to the administrator. Students are free to withdraw their participation at any point of the study without penalty after informing the Principal Investigator.

Principal Investigator

Guardian Informed Consent

I agree that I have read this informed consent fully. I fully understand the contents of this document and am openly willing to send my son/daughter to take part in this workshop on Prāṇāyāma and Vedic Maths.

All the queries related to participation of student were clarified to me and in case of any problem or further clarification I may contact the above mentioned persons.

Date:
Place:

Parent Name and Signature

2.3 Participant Informed Consent

Swami Vivekananda Yoga Anusandhana Samsthana, Bangalore

Study title: Evaluation of yogic breathing and vedic mathematics module in the management of math anxiety and cognitive skills in School children
Principal Investigator: Vasant V Shastri, Ph.D. Scholar, Division of Yoga and Physical Sciences, SVYASA, Bangalore. (contact Number: +919986415625)
Faculty Adviser: Dr. Sanjeev Patra, **Assistant Professor,** Division of Yoga and Life Sciences, SVYASA, Bangalore. (contact Number: +919483390476)

This form is designed to provide you with information about this study. The Principle investigator or representative will describe this study to you and answer any of

questions. If you have any questions or complaints about the informed consent process or the research study, please contact the Principal Investigator.

This study is to evaluate the Yogic breathing practices (Kapālabhāti, Nāḍī Śuddhi, Bhrāmarī) and Vedic Mathematics modules (Easy problem solving skills), in the management of math anxiety and cognitive skills in school going children. Students will participate in 15 days workshop on Yogic breathing Practices and Vedic Mathematics. In the unlikely event of student sustaining a physical or psychological injury arising out of this study, primary health care will be provided.

Assessments consist of cognitive tests and questionnaires which will be conducted through computer and paper pencil tasks. No potential risks are anticipated by undergoing these tests.
No other sensitive information is collected. All information obtained in this study is strictly confidential unless disclosure is required by law.

No incentives will be provided for participants. Students are free to express any discomfort or problem during workshop or test session to the administrator. Students are free to withdraw their participation at any point of the study without penalty after informing the Principal Investigator.

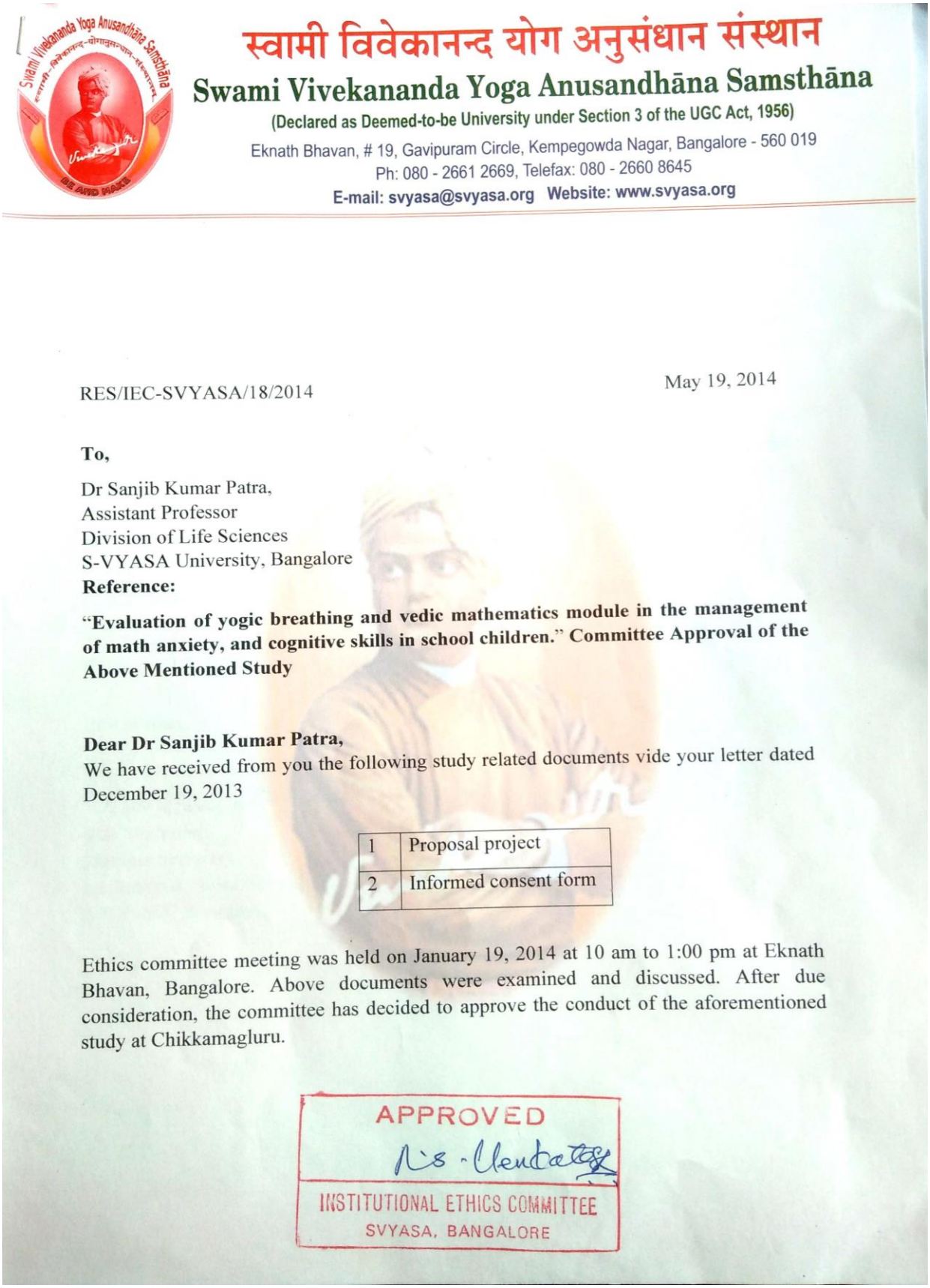
Principal Investigator

I agree that I have read this informed consent fully. I fully understand the contents of this document and am openly willing to take part in this study.
All the queries related to participation were clarified to me and in case of any problem or further clarification I may contact the above mentioned persons.

Date:
Place: Participant

APPENDIX 3.0

INSTITUTIONAL ETHICAL COMMITTEE APPROVAL



स्वामी विवेकानन्द योग अनुसंधान संस्थान
Swami Vivekananda Yoga Anusandhāna Samsthāna
(Declared as Deemed-to-be University under Section 3 of the UGC Act, 1956)
Eknath Bhavan, # 19, Gavipuram Circle, Kempegowda Nagar, Bangalore - 560 019
Ph: 080 - 2661 2669, Telefax: 080 - 2660 8645
E-mail: svyasa@svyasa.org Website: www.svyasa.org

RES/IEC-SVYASA/18/2014

May 19, 2014

To,

Dr Sanjib Kumar Patra,
Assistant Professor
Division of Life Sciences
S-VYASA University, Bangalore

Reference:

"Evaluation of yogic breathing and vedic mathematics module in the management of math anxiety, and cognitive skills in school children." Committee Approval of the Above Mentioned Study

Dear Dr Sanjib Kumar Patra,

We have received from you the following study related documents vide your letter dated December 19, 2013

1	Proposal project
2	Informed consent form

Ethics committee meeting was held on January 19, 2014 at 10 am to 1:00 pm at Eknath Bhavan, Bangalore. Above documents were examined and discussed. After due consideration, the committee has decided to approve the conduct of the aforementioned study at Chikkamagluru.

APPROVED
N.S. Venkatesh
INSTITUTIONAL ETHICS COMMITTEE
SVYASA, BANGALORE

स्वामी विवेकानन्द योग अनुसंधान संस्थान
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(Declared as Deemed-to-be University under Section 3 of the UGC Act, 1956)
Eknath Bhavan, # 19, Gavipuram Circle, Kempegowda Nagar, Bangalore - 560 019
Ph: 080 - 2661 2669, Telefax: 080 - 2660 8645
E-mail: svyasa@svyasa.org Website: www.svyasa.org

This is to confirm that neither Dr Sanjib Kumar Patra, nor any study staff participating in this study were involved in the voting procedures and decision making for these study documents.

The Institutional Review Board / Independent Ethics Committee expected to be informed about the progress of the study, any changes in the protocol and patient information / informed consent. The investigators are also expected to submit a copy of the final report to IEC for records.

This approval is valid up to the completion of the study at this site.

Please submit to the EC the status report of the study as per EC SOP's.

The EC is organized & operates according to the requirements of ICH – GCP, Indian Council of Medical Research guidelines & Schedule Y.

Best Wishes,

R.S. Venkatesh,
Member Secretary,
Institutional Ethics Committee,
S-VYASA, Bangaluru

APPENDIX 4.0

QUESTIONNAIRE(S) – SAMPLE COPY

4.1 MARS-R

Name_____Reg No_____

MARS-R

Please rate each item in terms of how anxious you feel during the event specified. Use the following scale and record your answer in the space to the left of the item:

1=Low anxiety
2=Some anxiety
3=Moderate anxiety
4=Quite a bit of anxiety
5=High anxiety

Learning mathematics anxiety

_____ 1. Watching a teacher work an algebraic equation on the blackboard.

_____ 2. Buying a math textbook.

_____ 3. Reading and interpreting graphs or charts.

_____ 4. Signing up for a course in statistics.

_____ 5. Listening to another student explain a math formula.

_____ 6. Walking into a math class.

_____ 7. Looking through the pages in a math text.

_____ 8. Starting a new chapter in a math book.

_____ 9. Walking on campus and thinking about a math course.

_____ 10. Picking up a math textbook to begin working on a homework assignment.

_____ 11. Reading the word 'Statistics'.

_____12. Working on an abstract mathematical problem, such as: 'if x= outstanding bills, and y= total income, calculate how much you have left for recreational expenditure.

_____ 13. Reading a formula in chemistry.

_____ 14. Listening to a lecture in a math class.

_____ 15. Having to use the tables in the back of a math book.

_____ 16. Being told how to interpret probability statements.

Mathematics evaluation anxiety

_____ 1. Being given a homework assignment of many difficult problems which is due the next class meeting.

_____ 2. Thinking about an upcoming math test one day before.

_____ 3. Solving square root problem.

_____ 4. Taking an examination (quiz) in a math course.

_____ 5. Getting ready to study for a math test.

_____ 6. Being given a 'pop' (unannounced) quiz in a math test.

_____7. Waiting to get a math test returned in which you expected to do well.

_____8. Taking an examination (final) in a math course.

4.2 CCAQ

INSTRUMENTS FOR CHILDREN (CCAQ)

Listed below are four sets of statements. Indicate whether each is true or false of your thoughts while taking the test by circling T (true) or F (false).

NEGATIVE EVALUATION

T	F	Others probably think I'm dumb.
T	F	I have a bad memory.
T	F	I'm doing poorly.
T	F	I can't do this – I give up.
T	F	Everyone usually does better than me.
T	F	I must be making many mistakes.
T	F	I don't do well on tests like this.
T	F	I am too dumb to do this.
T	F	I'm doing worse than the others.
T	F	I really feel stupid.

OFFTASK THOUGHTS

T	F	I wish I were playing with my friends.
T	F	I am nervous and worried.
T	F	I wish I were home.
T	F	I wish this was over.
T	F	My mind keeps on wandering.
T	F	I keep on daydreaming.
T	F	I wonder what the examiner is going to find out about me.
T	F	I can't seem to sit still.
T	F	Pretty soon I'll get to do something else.
T	F	I am hungry.

POSITIVE EVALUATIONS

T F I am fast enough to finish this.

T F I do well on test like this.

T F I usually do better than the others.

T F I am bright enough to do this.

T F This test is easy for me to do.

T F I am doing the best that I can.

T F I usually catch on quickly to new things.

T F I am doing better that than the others.

T F I am sure to do fine on this.

T F I am able to do well on different things.

ON TASK THOUGHTS

T F I stay calm and relaxed.

T F The harder it gets, the more I need to try.

T F Try a different plan.

T F One step at a time.

T F I have a plan to solve this.

T F Keep looking for a solution.

T F Work faster.

T F Pay attention.

T F I've almost got it now- keep working.

T F Don't think about anything but solving the problem.

4.3 MAAS

Day-to-Day Experiences

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

I could be experiencing some emotion and not be conscious of it until sometime later.	1	2	3	4	5	6
I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
I tend to walk quickly to get where I'm going without paying attention to	1	2	3	4	5	6
I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6
I rush through activities without being really attentive to them.	1	2	3	4	5	6
I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	1	2	3	4	5	6
I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6
I drive places on 'automatic pilot' and then wonder why I went there.	1	2	3	4	5	6
I find myself preoccupied with the future or the past.	1	2	3	4	5	6
I find myself doing things without paying attention.	1	2	3	4	5	6
I snack without being aware that I'm eating.	1	2	3	4	5	6

4.4 Nonphysical aggression scale

Nonphysical Aggression—Pittsburgh Youth Study

These items measure non-physical aggressive behavior. Youth are asked about the extent to which they engage in 16 non-physical aggressive behaviors such as arguing, bragging, seeking attention, disobeying parents or teachers, not getting along with others, swearing, and sulking.

	Not true	Sometimes true	Very true
1. You argue a lot.	0	1	2
2. You brag.	0	1	2
3. You try to get a lot of attention.	0	1	2
4. You disobey your parents.	0	1	2
5. You disobey at school.	0	1	2
6. You don’t get along with other kids.	0	1	2
7. You are jealous of others.	0	1	2
8. You scream a lot.	0	1	2
9. You show off or clown.	0	1	2
10. You are stubborn.	0	1	2
11. You swear or use dirty language.	0	1	2
12. You tease others a lot.	0	1	2
13. You have a hot temper.	0	1	2
14. You threaten to hurt people.	0	1	2
15. You are louder than other kids.	0	1	2
16. You sulk or pout a lot.	0	1	2

Scoring and Analysis

For the purposes of this construct, all positive responses are equivalent. Responses of 2 “very true” are recoded to 1 “sometimes true.” All scores are summed to derive a total. Higher scores indicate more aggressive behaviour.

4.5 ERQ

Emotion Regulation Questionnaire (ERQ)
Gross & John

The Emotion Regulation Questionnaire is designed to assess individual differences in the habitual use of two emotion regulation strategies: cognitive reappraisal and expressive suppression.

Citation

Gross, J.J., & John, O.P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. Journal of Personality and Social Psychology, 85, 348-362.

Instructions and Items

We would like to ask you some questions about your emotional life, in particular, how you control (that is, regulate and manage) your emotions. The questions below involve two distinct aspects of your emotional life. One is your emotional experience, or what you feel like inside. The other is your emotional expression, or how you show your emotions in the way you talk, gesture, or behave. Although some of the following questions may seem similar to one another, they differ in important ways. For each item, please answer using the following scale:

1----------2----------3----------4----------5----------6----------7

Strongly disagree	**neutral**	**strongly agree**

1. ____ When I want to feel more *positive* emotion (such as joy or amusement), I *change what I'm thinking about*.
2. ____ I keep my emotions to myself.
3. ____ When I want to feel less *negative* emotion (such as sadness or anger), I *change what I'm thinking about*.
4. ____ When I am feeling *positive* emotions, I am careful not to express them.
5. ____ When I'm faced with a stressful situation, I make myself *think about it* in a way that helps me stay calm.
6. ____ I control my emotions by *not expressing them*.
7. ____ When I want to feel more *positive* emotion, I *change the way I'm thinking* about the situation.
8. ____ I control my emotions by *changing the way I think* about the situation I'm in.
9. ____ When I am feeling *negative* emotions, I make sure not to express them.
10. ____ When I want to feel less *negative* emotion, I *change the way I'm thinking* about the situation.

Note

Do not change item order, as items 1 and 3 at the beginning of the questionnaire define the terms "positive emotion" and "negative emotion".

Scoring (no reversals)

Reappraisal Items: 1, 3, 5, 7, 8, 10; Suppression Items: 2, 4, 6, 9.

4.6 Demographic data

SOCIO DEMOGRAPHIC QUESTIONNAIRE

- Name:
- Age (Yrs):
- Registration number (mentioned on School ID):
- Gender (Male/ Female) : Religion:
- Education :
- Parents qualification : Father – Education:

  Occupation:

  Mother - Education:

  Occupation:
- Languages known:
- Address :

- Phone No.:
- Diet (Veg/Non veg):
- Hours of sleep (5hrs / 6hrs / 7hrs / 8hrs / 9hrs):
- Activities indulged in last 1 month (PT / sports / dance / Yogä / gym / other / none of these):
- Did you practice Yogic Breathing (Präëäyäma) before? How long? (Yes / No):
- Did you practice Vedic Maths before? How long? (Yes / No):
- Are you suffering by any eyesight problem? (Yes / No):

If yes mention the problem with vision:

- Are you suffering by colour blindness? (Yes / No):
- Are you undergoing any Psychiatric treatment? (Yes / No)
- Are you undergoing any medical treatment from past one month or before? (Yes / No)
- If yes, please mention the problem(s) and years of problem(s):

- Percentage of marks in last examination:
- Percentage of marks in last mathematics examination:
- Are you suffering by any disease or injury? (Yes / No)

  If yes mention the disease or injury. How long? :

- Your Favourite subject(s):
- How many hours do you study per day
- How many hours do you watch TV per day
- How many hours you sit in front of computer per day
- Is your parents native of Karnataka
- Language spoken at home

APPENDIX 5

ABBREVATIONS

1. VM – Vedic Maths
2. YP – Yogā Prāṇāyāma
3. JG : Jogging Group
4. CCAQ : Children's Cognitive Assessment Questionnaire
5. MARS-R: Mathematics Anxiety Rating Scale Revised
6. MAAS: Mindfulness Attention Awareness Scale
7. ERQ: Emotion Regulation Questionnaire
8. LMA: Learning Math Anxiety
9. EMA: Evaluation Math Anxiety
10. TMA: Total Math Anxiety

APPENDIX 6

LIST OF PUBLICATIONS FROM THIS DOCTORAL THESIS

Shastri, V., Hankey, A., Sharma, B., & Patra, S. (2016). Efficacy of vedic mathematics and yogic breathing in school children: A pilot study. *International Journal of Yoga - Philosophy, Psychology and Parapsychology*, *4*(1), 16–23. http://doi.org/10.4103/ijny.ijoyppp_3_16

Shastri, V., Hankey, A., Sharma, B., & Patra, S. (2017b). Investigation of yoga pranayama and vedic mathematics on mindfulness, aggression and emotion regulation. *International Journal of Yoga*, *10*(3), 138–144. http://doi.org/10.4103/0973-6131.213470

Shastri, V., Hankey, A., Sharma, B., & Patra, S. (2017a). Impact of pranayama and vedic mathematics on math anxiety and cognitive skills. *Yoga Mimamsa*, *49*(2), 53–62. http://doi.org/10.4103/ym.ym_13_17

Original Article

Efficacy of Vedic Mathematics and Yogic Breathing in School Children: A Pilot Study

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Abstract

Background: Anxiety can cause problems in examination performance, particularly mathematics. This study aimed to compare two methods of reducing math anxiety in 8th–10th standards, Yoga pranayama and Vedic mathematics (VM). We report a randomized controlled trial comparing effects of these on working memory, math anxiety, and cognitive flexibility. **Subjects and Methods:** Forty higher secondary students, resident at Sri Sai Angels School Chikkamagaluru were randomly assigned to Yogic Breathing, VM, and Jogging (JG) groups with 14, 13, and 13 children, respectively. **Intervention:** Children in Yoga breathing (YB) and VM groups attended 7-days' workshop on Pranayama and VM, respectively. Others went JG every day. **Assessments:** Mathematics Anxiety Rating Scale-Revised, STROOP test, Children's Cognitive Assessment Questionnaire, and digit span test were administered pre and post the intervention. **Analysis:** SPSS-17 was used for nonparametric pre-post comparison tests (Wilcoxon) and group comparisons tests (Mann–Whitney). **Results:** Math anxiety decreased most in VM (−11.77 ± 10.47; $P < 0.01$). Others: YB (−4.08 ± 4.99; $P < 0.05$); JG, (−3.75 ± 16.94). Changes in cognitive flexibility and reaction to cognitive stress were VM (+9.77 ± 5; $P < 0.001$); YB (+5.38 ± 5.38; $P < 0.01$) and JG (+8.58 ± 9.91; $P < 0.05$). Self-defeating cognition scores decreased in YB (−1.77 ± 1.83; $P < 0.01$) and VM (−1.38 ± 3.2), but not JG (+0.67 ± 1.44). Digit span scores were similar in all groups. **Conclusion:** VM and YB showed small improvement in cognitive skills and decrease in math anxiety compared to JG. The study suggests that a 7-day VM workshop can decrease math anxiety, which might help enhance cognitive skills. Calming effects of pranayama practices are the probable cause for YB group improvements.

Keywords: *Cognitive skills, math anxiety, pranayama, school children, Vedic mathematics*

Introduction

To qualify for better career options when leaving school, good abilities in mathematics and associated cognitive skills are important. Students with math anxiety show strong tendencies to avoid mathematics, however.[1,2] High math anxiety, low working memory, and poor math performance have been shown to be strongly correlated.[3-5] High math anxiety correlates with low self-concept, suggesting that it deeply undermines student self-confidence.[6] Math anxiety can also influence a student's decision-making abilities[7] so that stressful situations can have immediate physiological impact, for example, difficulty in breathing, increased heart rate, upset stomach, and light-headedness.[8]

Many methods have been studied and applied to reduce math anxiety or to improve math performance in school children.[8,9] Yoga has consistently proved

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an effective way to reduce anxiety; the power of Yoga breathing (YB) exercises to do so has been well characterized, and they are now well understood. A completely different approach is offered by the program of Vedic mathematics (VM), which has proved popular in schools that have adopted it and is said to improve performance (James Glover, Kenneth Williams: private communication), though no quantitative results have yet been reported. Out of concern to help improve student performance on professional math examinations the present study aimed to compare the effects of VM and YB modules on math anxiety and related cognitive skills in high school students aged 13–15.

Vedic mathematics

The methods of VM were first suggested by Swami Bharati Krsna Tirtha, the Shankaracharya of Puri (1884-1960), in a posthumously published book of that title.[10] They have been applied in many schools in various different countries worldwide, and widely expanded in their possible applications. High school mathematics has long been a popular application, possibly because before becoming a monk, the Shankaracharya was a teacher of high school mathematics. He may well have tailored his cognitions so that they would have useful applications at that level. They have certainly proved popular in that context, with many students privately reporting greater enjoyment of solving math problems, even those with little previous enjoyment of mathematics.

VM consists of 16 *sūtras* (formulae), each of which suggests a particular pattern to solve some kind of math problem, along with 16 *upasūtras* (subformulae). Having learned the sutras and their possible applications, students can then choose whichever most appeals to them to solve any problem with which they are faced. One possible way that VM may help student confidence could, therefore, be by suggesting different strategies involving fewer steps to solve a given math problem. Offering such choice of alternative solutions can help students feel that math classes are entertaining. Classes can become amusing sessions of pattern finding in the form of interesting, alternative VM algorithms, appropriate to solving particular problems. These can be easily and effectively presented by school teachers, and function as teaching aids to handle math anxiety;[11] they also improve cognitive load, so certain VM techniques may be hypothesized to have a positive impact on working memory.

VM is not a new branch of mathematics, but a set of unique approaches to simplifying problem-solving. The sutras and upasutras suggest thinking patterns to help solve arithmetical, algebraic, or geometric calculations common in high school mathematics.[12] VM patterns reduce cumbersome-looking calculations in the conventional approach to simple ones.[13]

They have also been applied in digital signal processing such as construction of shortest algorithms for multipliers in circuits to optimize chip area[14-16] and other similar applications. In multiplier circuits, the pattern given in the *Urdhva Tiryakbhyam* sutra gives the most efficient algorithm, minimizing delays for multiplication of all types of numbers.[17] Such applications of VM algorithms improve efficiency of machines rather than mental processes.

Shortened algorithms for mental calculations may impact cognitive processes, however, eventually improving math anxiety and performance.[7] VM methods have not previously been investigated as teaching aids in educational and cognitive research. Here, we report results of using a VM module both to develop cognitive skills and manage math anxiety.

Yogic breathing (pranayama)

Yoga pranayama is well known to improve conditions in both clinical and nonclinical situations. Evidence that pranayama reduces stress levels and improves individual well-being is strong.[18] Pranayama has also been found to decrease state and trait anxiety levels.[19]

Uninostril breathing (left nostril breathing or right nostril breathing) and alternate nostril breathing (Nadishodhana pranayama) can bring positive changes in cognitive tasks.[20] They may help sharpen the critical faculty and creativity and may also bring balance between the left and right halves of the brain.[21] In addition, Kapalabhati, Bhastrika, and Nadishodhana, i.e. both fast and slow pranayamas, and Pranava (OM) chanting can be used to reduce stress levels and to improve cognitive skills, particularly working memory.[22]

Methods

Subjects

Forty boys studying in 8th, 9th, 10th standards, at Sri Sai Angels School, Chikkamagaluru, were randomly assigned to: Yogic breathing group (YB – 14), VM group (VM – 13), and Jogging (JG) group (JG – 13). The design of the study was explained to parents/guardians, and signed informed consent was obtained.

Design

Three group, pre-post random control design [Figure 1]. Randomization was performed using an internet random number generator.[23]

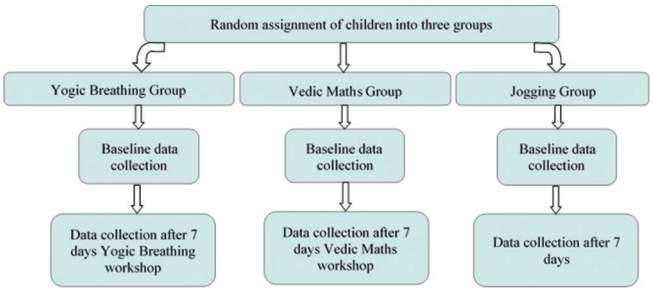

Figure 1: Study design: The sample was divided randomly (with the help of random number generator) into three groups: Yoga breathing, Vedic mathematics, and Jogging. The baseline data were collected, and then respective intervention was given for 7 days to the groups. Postdata were collected after the intervention

Assessment instruments used

Mathematics Anxiety Rating Scale-Revised

This 24-item instrument is designed to measure anxiety related to involvement in statistics and mathematic courses.[24] The instrument is a revised version of a 98-item scale by Richardson and Suinn.[25] The current version is more focused on situation specific (state) anxiety, general (trait) anxiety, and test anxiety. The instrument comprises two subscales: Learning mathematics anxiety (LMA) which pertains to the process of learning of math and statistics; and evaluation mathematic anxiety (EMA) measuring anxiety over tests on math and statistics. The sum of LMA and EMA is taken as total mathematics anxiety (TMA).

Scoring - Respondents rate each item on a 5-point scale from "low anxiety" to "high anxiety." Scores are the sum of the item ratings and range from 24 to 120 for the total scale.

STROOP

The STROOP test consists of three subtasks measuring cognitive flexibility, creativity, and reaction to cognitive stress.[26] J.R. Stroop first developed it in 1935.[27] The test consists of three subtasks. The stimulus material for each of these subtasks is shown on a white sheet of paper. The 100 stimuli for each subtask are distributed evenly in a 10×10 matrix on each sheet of paper. The first subtask shows colour words in random order (red, blue, yellow, green) printed in black ink. Subtask 2 displays solid colour patches in one of these four basic colours. The third subtask contains colour words printed in an incongruous ink colour for example, the word yellow printed in red ink. The subject's task on the word subtask is to read aloud the colour words; on the colour to name the coloured patches or asterisks; and on the colour word to name the colors of the ink, ignoring the printed color word. Maximum of 45 seconds per subtask was given to the subject. Scoring was done using number of item completed on each subtask.

Children's Cognitive Assessment Questionnaire

This 40-item instrument measures self-defeating and self-enhancing cognitions associated with test-anxiety.[28] The instrument was originally developed for hypothesis testing on the relationship between cognition and test-anxiety or task performance. The theoretical perspective asserts that self-defeating thoughts inhibit performance while self-enhancing thoughts facilitate it. The Children's Cognitive Assessment Questionnaire (CCAQ) focuses on negative self-evaluations (NSEs) and positive self-evaluations as reflecting self-defeating and self-enhancing cognitions, respectively. It also assesses self-distracting thoughts ("off-task thoughts;" [OFFT]) and cognitions which focus one's attention on the task ("on-task thoughts"). The CCAQ uses these four aspects as subscales.

Scoring - Each of 40 items is answered true or false, scoring 1/0. Total score for each subscale is the number of items answered "true", ranging from 0 to 10. Higher scores reflect more thoughts indicative of test-anxiety.

Digit span test

This test measures working memory.[29] Here, we used the 2011 computerized version of the Digit span test developed by Inquisit software.[30] Each participant is given 14 trials observing a sequence of digits (starting with three digits-level 3), presented for 1 s each, after which the participant is asked to recall the digit sequence and type the answer into a presented textbox. If the response is correct (in digits and presentation order), the participant moves up to the next level (e.g., level 4). If the response is incorrect, the same level is presented a second time. If a consecutive error occurs, the participant moves back down to a lower level, starting over.

The first time a participant makes a consecutive error, span is set to the last correctly recalled number of digits (e.g., if participant reaches level 8, but answers incorrectly both times, the span is set to 7).

Interventions

YB group and VM group students attended workshops on Pranayama and VM (Appendix I), respectively, (30 min at 6.00 am and 6.30 am, respectively, every day for 7 days). Those in the JG group went for 30 min JG every day at 5.30 am.

Data extraction

Mathematics Anxiety Rating Scale-Revised (MARS-R), CCAQ, digit span test and STROOP test were given at baseline, and after the 7-day VM and YB workshops were completed.

Data analysis

The data were analyzed using SPSS 17.0 (Seattle, Washington, United States). Due to small group size, nonparametric tests were used: Mann–Whitney test for inter-group comparisons and Wilcoxon test for within group pre-post comparisons.

Results

There were no baseline differences between the three groups in all the variables studied except offtask thoughts for the JG Group, for which the baseline score was significantly different from other two groups ($P < 0.05$).

Results for the three groups, YB, VM, and JG, were as follows:

Math anxiety Rating Scale

VM group showed significant pre-post differences in TMA (pre 57.85 ± 14.43; post 46.08 ± 14.38; $P < 0.01$), LMA (pre 34.69 ± 8; post 29 ± 9.23; $P < 0.05$), and EMA (pre 23.15 ± 7.8; post 17.08 ± 6.22; $P < 0.01$) [Table 1].

Yoga group showed significant differences in MARS-R in pre-post measures. Of the two subsets, EMA was significantly different between pre-post measures (pre 20.85 ± 7.35; post 17.15 ± 4.38, $P < 0.05$), but not LMA; TMA was still significantly lowered (pre 51 ± 14.3; post 46.92 ± 12.63, $P < 0.05$) [Table 1].

JG group showed no significant differences between pre-post measures [Table 1].

Comparisons of pre-post differences between the three groups: LMA and TMA differences between Yoga pranayama and VM groups were significant ($P < 0.05$) [Table 1]; this could have been due to lower pre values in yoga group. In contrast, the JG group was not significantly different in any of the three parameters from either of the other groups [Table 1].

STROOP test

VM group showed significant difference in color score (pre 61.23 ± 7.44; post 66.85 ± 10.64; $P < 0.05$) and color word (pre 34.15 ± 7.45; post 43.92 ± 9.06; $P < 0.001$). Pre-post differences in means of color word were not significant [Table 2].

YB showed significant difference in color word test of the STROOP test (pre 35.46 ± 5.98; post 40.85 ± 7.89; $P < 0.005$) [Table 2].

In JG group, significance was observed in word score (pre 86.58 ± 13.27; post 93.5 ± 12.38; $P < 0.05$) and color word (pre 31.33 ± 6.4; post 39.92 ± 9.03; $P < 0.05$) [Table 2].

No significant difference was observed between three groups on the STROOP test.

Children's Cognitive Assessment Questionnaire

VM group showed highly significant difference in pre-post values of OFFT (pre: 6.08 ± 1.61; post: 2.62 ± 2.66; $P < 0.001$) [Table 3].

YB Group showed significant improvement in lowering NSE (pre: 2.77 ± 2.01; post: 1 ± 1; $P < 0.01$) and OFFT (pre: 5.54 ± 2.57; post: 3.38 ± 2.36; $P < 0.01$) [Table 3].

JG group also showed significant difference in pre-post values of OFFT (pre: 7.42 ± 2.91; post: 5.92 ± 2.35; $P < 0.05$) [Table 3].

Pre-post differences analyses between the three groups suggest that YB and JG were significantly different in NSE (YB: −1.77 ± 1.83; JG: 0.67 ± 1.44; $P < 0.05$) [Table 3].

Digit span test

All the three groups performed equally in forward and backward digit span tests [Table 4].

Table 1: Mathematics Anxiety Rating Scale-Revised: Mean±standard deviation

	YB	YB (pre-post difference)	VM	VM (pre-post difference)	JG	JG (pre-post difference)
LMA						
Pre	30.15±8.28	−0.38±3.04*	34.69±8	−5.69±7.08*	34.75±8.41	−2.08±10.83
Post	29.77±8.53		29±9.23*		32.67±9.88	
EMA						
Pre	20.85±7.35	−3.69±5.36	23.15±7.8	−6.08±6.24	22.5±6.27	−1.67±8.86
Post	17.15±4.38*		17.08±6.22**		20.83±8.49	
TMA						
Pre	51±14.3	−4.08±4.99*	57.85±14.43	−11.77±10.47*	57.25±11.34	−3.75±16.94
Post	46.92±12.63*		46.08±14.38**		53.5±17.68	

Pre- and post-mean±SD as well as three group 'pre-post differences' comparison of YB, VM and JG groups on Digit span test. Within group significant differences are indicated next to the post score, while between group significant differences are indicated next to both pre-post scores. Significant differences are shown by *P<0.05 and **P<0.01. YB=Yoga breathing, VM=Vedic mathematics, JG=Jogging, MARS-R=Mathematics Anxiety Rating Scale-Revised, SD=Standard deviation, LMA=Learning mathematics anxiety, EMA=Evaluation mathematic anxiety, TMA=Total mathematics anxiety

Table 2: STROOP test: Mean±standard deviation

	YB	YB (pre-post difference)	VM	VM (pre-post difference)	JG	JG (pre-post difference)
Word score						
Pre	95.15±11.26	4.00±7.15	97.85±16.34	4.85±9.26	86.58±13.27	6.92±8.08
Post	99.15±15.57		102.69±15.23		93.5±12.38*	
Color score						
Pre	61.69±8.44	3.54±8.58	61.23±7.44	5.62±8.14	61.17±6.69	3.67±7.01
Post	65.23±11.1		66.85±10.64*		64.83±12.09	
Color word						
Pre	35.46±5.98	5.38±5.38	34.15±7.45	9.77±5.00	31.33±6.4	8.58±9.91
Post	40.85±7.89**		43.92±9.06***		39.92±9.03*	

Pre- and post-mean±SD as well as three group 'pre-post differences' comparison of YB, VM and JG groups on STROOP test. Within group significant differences are indicated next to the post score, while between group significant differences are indicated next to both pre-post scores. Significant differences are shown by *P<0.05, **P<0.01 and ***P<0.001. YB=Yoga breathing, VM=Vedic mathematics, JG=Jogging, SD=Standard deviation

Table 3: Children's Cognitive Assessment Questionnaire: Mean±standard deviation

	YB	YB (pre-post difference)	VM	VM (pre-post difference)	JG	JG (pre-post difference)
Negative evaluations						
Pre	2.77±2.01	−1.77±1.83*	3.08±3.25	−1.38±3.2	2.83±1.99	0.67±1.44*
Post	1±1**		1.69±2.75		3.5±2.58	
Off-task thoughts						
Pre	5.54±2.57	−2.15±2.15	6.08±1.61	−3.46±3.04	7.42±2.91	−1.5±2.2
Post	3.38±2.36**		2.62±2.66***		5.92±2.35*	
Positive evaluations						
Pre	7.77±1.92	0.62±2.33	7.15±2.64	−0.77±3.03	8±2.22	−1±2.09
Post	8.38±1.94		6.38±3.31		7±2.89	
On-task thoughts						
Pre	8.15±1.52	−0.08±1.32	6.85±3.05	0.46±2.79	7.5±1.68	0.42±2.35
Post	8.08±1.98		7.31±3.07		7.92±1.83	

Pre- and post-mean±SD as well as three group 'pre-post differences' comparison of YB, VM and JG groups on Children's Cognitive Assessment Questionnaire. Within group significant differences are indicated next to the post score, while between group significant differences are indicated next to both pre-post scores. Significant differences are shown by *P<0.05, **P<0.01 and ***P<0.001. YB=Yoga breathing, VM=Vedic mathematics, JG=Jogging, SD=Standard deviation, CCAQ=Children's Cognitive Assessment QuestionnaireSD=Standard deviation, CCAQ=Children's Cognitive Assessment Questionnaire

Table 4: Digit span test: Mean±standard deviation

	YB	YB (pre-post difference)	VM	VM (pre-post difference)	JG	JG (pre-post difference)
Forward digit span						
Pre	6.17±0.58	0.50±0.80	6.75±0.87	0.50±1.00	6.00±0.82	0.40±0.70
Post	6.67±0.65		7.25±1.22		6.40±0.70	
Backward digit span						
Pre	6.75±0.87	0.50±1.17	6.50±1.51	0.75±1.36	6.10±0.88	0.50±0.71
Post	7.25±0.75		7.25±0.87		6.60±0.70	

Pre- and post-mean±SD of the YB, VM, and JG groups on digit span test - forward and backward digit span. Pre-post differences of the three groups as well, using Wilcoxon test. YB=Yoga breathing, VM=Vedic mathematics, JG=Jogging, SD=Standard deviation

Discussion

This paper reports comparative effects of three interventions on math anxiety by MARS-R; cognitive flexibility and selective attention by the STROOP test; self-defeating and self-enhancing thoughts by CCAQ; and working memory by the digit span test. All three interventions appeared to influence the various measured parameters, to varying degrees.

Math anxiety with its two subscales, learning math anxiety, and evaluation math anxiety is the primary variable. VM

brought the most benefit for math anxiety levels, followed by YB [Figure 2]. JG did not reduce Math anxiety levels to any significant extent. Why the VM group received the most benefit compared to the other groups is obvious: it directly enhances math problem-solving skills bringing confidence to students concerned about math ability.

The VM group also showed the greatest improvement on the STROOP test [Figure 3]. The JG group's initial values were lower than those of the other two groups on word score, and its final (post) value did not even reach the pre-values of the other two groups [Table 2 and Figure 3]. These measurements seem confusing and require further investigation.

Scores on the CCAQ test measuring self-defeating and self-enhancing thoughts improved most for the Yoga group followed by the VM group [Figure 4]. The JG group's initial negative evaluation increased but not significantly [Table 3].

The digit span test, which measures working memory and focused attention,[31] did not show significant change after any intervention, nor between any pair of groups [Figure 5]. This result may be due to low sample size and the short intervention period. It needs further investigation.

Overall, VM tended to show greater results than the other interventions on all parameters. VM offers different possible strategies of mental calculation in smaller numbers of steps, bringing "a feel-good factor" to solving lengthy problems. Its methods promote pattern recognition in math,[32] introducing a fun element, possibly by stimulating "feel good" neurotransmitters release (dopamine, serotonin, and an array of endorphins).[33] Improvement in working memory, and reduction in math anxiety result.

YB practices, including repetitive chanting of A, U, M, OM, and generating a humming sound in Shambhavi Mudra, may stimulate the brain, eventually yielding stronger pattern recognition.[34] They may also stimulate the dopamine and endorphin system.[35] Cognitive

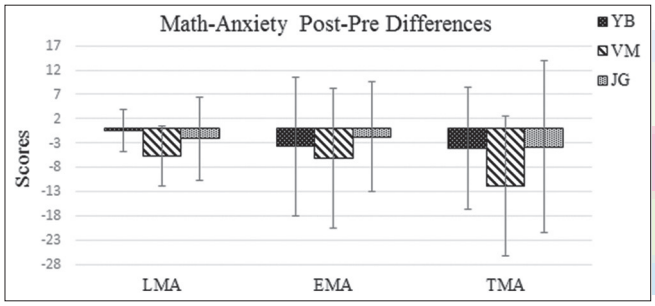

Figure 2: Comparison of math anxiety pre-post differences between Yoga breathing, Vedic mathematics, and Jogging groups: Pre-post differences of all three math anxiety score: Learning math anxiety, evaluation math anxiety, and total math anxiety, between all three groups, i.e., Yoga breathing, Vedic mathematics, and Jogging. Vedic mathematics group showed greater reduction in math anxiety, followed by Yoga breathing group. Standard deviations are shown by error bars

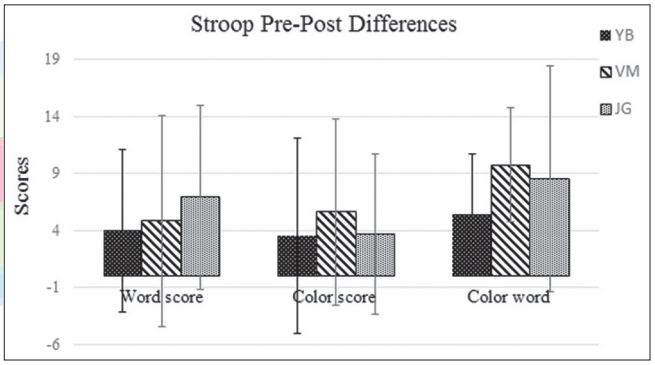

Figure 3: Comparison of STROOP pre-post differences scores between Yoga breathing, Vedic mathematics, and Jogging groups: Comparison of pre-post differences of all three parameters of STROOP test score: Word score, color score, and color word score, between all the three groups, i.e., Yoga breathing, Vedic mathematics, and Jogging. Vedic mathematics group showed greater increase in color and color word scores. Jogging group showed maximum increase in word score. Standard deviations are shown by error bars

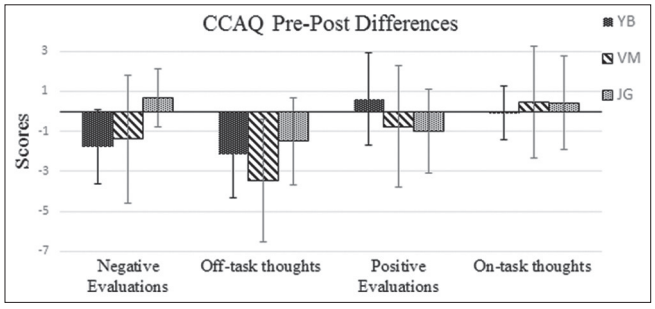

Figure 4: Comparison of Children's Cognitive Assessment Questionnaire pre-post differences scores between Yoga breathing, Vedic mathematics, and Jogging groups: Compare the pre-post differences of all four parameters of Children's Cognitive Assessment Questionnaire, between all the three groups, i.e., Yoga breathing, Vedic mathematics, and Jogging. Vedic mathematics group showed greater reduction in Off-task thoughts, followed by Yoga breathing group. Yoga breathing was observed to have greater reduction in negative evaluation and maximum increase in positive evaluations. Standard deviations are shown by error bars

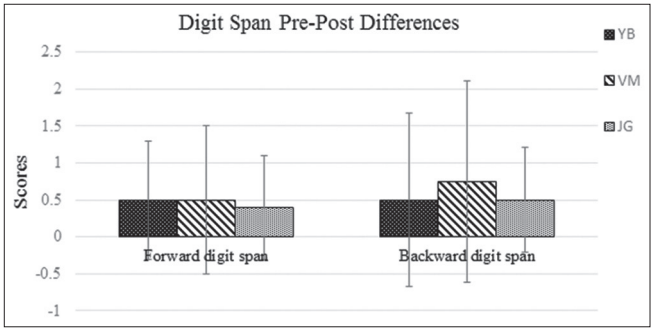

Figure 5: Comparison of digit span pre-post differences scores between Yoga breathing, Vedic mathematics, and Jogging groups: Comparison of digit span pre-post differences: forward and backward span, between all the three groups, i.e., Yoga breathing, Vedic mathematics, and Jogging. Standard deviations are shown by error bars

flexibility, creativity, and reaction to cognitive stress and math anxiety all improve slightly.

Yogic breathing brought greater improvements in CCAQ than the other interventions, strengthens the impact of Yoga in decreasing stress and improving self-concept and self-esteem,[36] which may lead to greater self-confidence, and result in better performance.[37] This may also lead to reduction in math anxiety.

The combined effect of these practices may therefore be of value in managing math anxiety and enhancing cognitive skills. The study brings a new understanding of VM and may introduce a new domain for its application. It also offers reasons for including VM and Pranayama, individually or together, in the school curriculum.

Strength of the study

Observed improvements in working memory, math anxiety, and focused attention, resulting from learning VM are new, as are those produced by practicing pranayama.

Limitation

As a pilot study, the sample size was too small to draw any strong conclusions. The intervention of 1 week is not enough make results conclusive.

Further research

Follow-up studies with larger group sizes are called for – one such has recently been accepted for publication;[38] also studies investigating mechanisms behind the observed changes.

Conclusion

The VM and YB modules were found useful in decreasing math anxiety, self-defeating thoughts and improving cognitive flexibility and self-enhancing thoughts in school children. Increasing sample size and intervention time may help generate stronger conclusions, and thus provide the grounds for implementing both techniques in school curricula.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Appendix

Appendix 1

To clarify readers understanding of Vedic mathematics, three worked examples are given:

Example 1: Find highest common factor (HCF) of $x^2 + 6x + 5$ and $x^2 + 4x - 5$

Sub sutra used: Sankalana − Vyavakalanam suggests that subtracting 2nd equation from the 1st one and equating it to zero we get HCF.

Answers: $x^2 + 6x + 5$

$x^2 + 4x - 5$

(−) (−) (+)

$2x+10$ equating this to zero we get HCF=$x+5$.

Example 2: Solve $\frac{1}{x+1}+\frac{1}{x+2}=0$.

Using the rule "Samuccaya" we get $x + 1 + x + 2 = 0$; $x=\frac{-3}{2}$.

The rule suggests that the sum of denominators of two rational expressions having the same numerical numerator is zero as shown above.

Example 3: Solve $\frac{x}{x+4}+\frac{x+4}{x}=\frac{122}{11}$

$$\frac{x}{x+4}+\frac{x+4}{x}=11+\frac{1}{11}\Rightarrow\frac{x}{x+4}=11\text{or}\frac{x+4}{x}=\frac{1}{11}$$

$$\Rightarrow x=\frac{-22}{5}\text{or}\frac{2}{5}$$

Original Article

Investigation of Yoga Pranayama and Vedic Mathematics on Mindfulness, Aggression and Emotion Regulation

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Abstract

Background: Competitive examinations, particularly in mathematics, have made emotional stress a major problem for preuniversity students, emotions like aggression toward fellow students and teachers increase. Mindfulness is a quality that reduces both emotional stress and aggression, so increasing mindfulness should be helpful. **Aims:** To study the effects of Yoga Pranayama (YP) and Vedic Mathematics (VM) on mindfulness, aggression, and emotion regulation. **Methods:** Participants were 12th graders attending a preuniversity college in Chikkamagaluru, India, of both genders. Exclusion criteria included major psychological problems. Three classes were arbitrarily assigned to one of three interventions, which consisted of 15 days each of 30 min daily instruction in YP, Group 1, VM, Group 2, or 30 min ordinary class work, Group 3, the control group. Assessments were made using the Mindfulness Attention Awareness Scale, the Nonphysical Aggression Scale from Pittsburgh Youth Study, and the Emotion Regulation Questionnaire. **Statistical Analysis Used:** SPSS 19.0. **Results:** Mindfulness, aggression, and negative emotional regulation changed significantly for the YP group, while mindfulness alone improved significantly for the VM group. No group changed on positive emotion regulation. Controls apparently improved on aggression. An interesting *post hoc* correlation analysis is also reported, among other things directly linking increased mindfulness to decreased aggression. **Conclusions:** The study showed positive effects of traditional methods of decreasing emotional pressure on students facing preuniversity mathematics examinations. Increasing mindfulness is considered a way of increasing emotion regulation, so the failure of this study to provide evidence for that is of interest.

Keywords: *Aggression, emotion regulation, mindfulness, Pranayama, Yoga*

Introduction

In recent years, stress has become a major factor affecting lives of children facing competitive professional examinations in the years before university.[1] This may be due to monotonous book-based teaching methods, which have created learning difficulties in education.[2] Mathematics is a subject that many students find very challenging and which can increase students' reported levels of stress[3] more than other subjects. Most high paid private sector jobs like basic engineering or other professional degrees require mathematics as a major subject. These circumstances have made emotional stress a major problem for students attempting to enter the college or university course of their choice.[4] Frustration can lead to increase in aggression[5] toward teachers and fellow students, and other antisocial behavior patterns.[6] In schools, competitive professional examinations select those entering higher education for various professions. Today, they put new pressures and workloads on schoolchildren that some even argue to be unnecessary. Reducing the effects of such pressures is a matter of national urgency.

The concept of mindfulness comes from the Pali concept of *sati*,[7] i.e., being aware of one's stream of consciousness, thinking patterns, and associated tendencies to action in the present moment.[8] Recent years have seen the publication of many studies on the quality of mind known as mindfulness[9] including studies of mindfulness training in schools.[10] Attempts have been made to design mindfulness-based education programs to improve the quality of teaching and learning.[11] Mindfulness is said to reduce aggression[12] and improve emotion regulation.[13,14] This study reports effects of two easily applied methods, Yoga Pranayama (YP) and Vedic Mathematics (VM), aiming to decrease

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emotional stress and aggression and increase mindfulness in preuniversity students facing competitive entrance examinations particularly in mathematics. An integrated Yoga intervention including Yoga postures, breathing exercises, and relaxation which have been reported to improve both mindfulness and emotional balance,[15] as well as cognitive performance,[16] but to our knowledge, the effect of teaching mathematics according to the methods of VM has not been studied in this context nor have the effects of YP alone been evaluated for effects on mindfulness.

Yoga Pranayama

Pranayama is the fourth of the eight limbs of Yoga[17] and has a deeply settling influence on the mind[18] helping the subject be in the present, i.e., "mindful." It is, therefore, widely employed as a preparation for meditation.[8] It enlivens prana, or "subtle energy" in the tissues, now measured electrically at acupuncture points.[19] Its settling influence has been confirmed by such observations as test anxiety reduction, improved test performance,[20] and perceived stress reduction and improvement in cardiovascular parameters;[21,22] it also reduces aggression.[23] These results suggest that application of pranayama methods to decrease effects of stress in society might prove valuable. Teaching them in schools would make a highly beneficial life-long skill available[24] just as mindfulness-based interventions (MBI) are seen as achieving.[10]

Hence, so many studies have been published on various pranayama programs that its effects may be considered quite well standardized. It can be used as a comparison for another method requiring assessment for comparative effects. In this context, YP represents a recognized way of managing mild levels of stress, and so improving emotion regulation and decreasing tendencies to aggression. In particular, pranayama practice usually involves focusing on the breathing process bringing the mind to the present moment. Improving that ability will clearly be of value when taking tests and exams.

Vedic Mathematics

VM[25] presents a new method of problem-solving in high school mathematics comprising 16 sutras and 16 upasutras, which have been much appreciated wherever they have been applied.[26] According to Charak (2002) (Quoted on back cover of Glover [2005]), "They make arduous mathematical situations look terribly simple to solve. I have taught … the principles … to my students in B.Ed. classes. They found the techniques extremely simple, less time consuming, and less likely to lead to mistakes."[26] We have found that they offer students choice when performing calculations, thus introducing a "fun" element and increasing student enthusiasm. As a result, mathematics teachers in many different countries have extended their applications.[27]

The system's ability to empower students to choose how to perform calculations means that students can select their preferred method in arithmetic, algebra, geometry, etc. Its use helps to develop students' confidence and basic problem-solving abilities. Visualizing pictorial or algebraic patterns to solve problems increases students' enjoyment of the process.[28] Problem-solving calculations become a game.

This approach of VM allows teachers to give detailed reasons for the success of each method. In our estimate, a mature approach teaches VM not as a set of magical tricks but as teaching aids to communicate deeper aspects of a problem's structure and solution. In short, enabling students to visualize how and why each method works, resulting in added understanding, and increased confidence when faced with exam questions. A previously submitted paper has reported reductions in mathematics anxiety (Impact of Pranayama and VM on Math Anxiety and Cognitive Skills, submitted for publication). On this basis, we hypothesized that using VM would improve mindfulness and emotional regulation and reduce aggression in school students, particularly those in 11th and 12th grades.

Methods

Participants

Three classes totaling 243 students studying in 12th Standard at Sri Sai Angels Preuniversity College, Chikkamagaluru, India, were arbitrarily assigned to YP group (YP – 73 students), VM group (VM – 80 students), and control group (CG – 90 students).

Design

Three group, pre–post control design [Figure 1].

Data extraction

Pencil and paper tests on Mindfulness Attention Awareness Scale (MAAS), Nonphysical Aggression Scale from Pittsburgh Youth Study and Emotion Regulation Questionnaire (ERQ) as described below were given at baseline and after the 15-day intervention workshops.

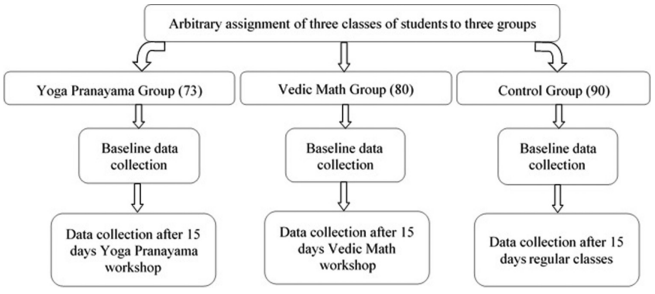

Figure 1: Three classes of 12th grade preuniversity students were arbitrarily assigned to one of three interventions: Yoga Pranayama, Vedic Mathematics, and Controls. Baseline data were collected following which the respective intervention was given for 15 days to each group. Postdata were collected after the intervention

Interventions

Students in the YP and VM groups participated in half hour workshops on their respective topics every day for 15 days [Table 1]. Controls had their usual conventional mathematics classwork routine, whereas the first two groups received respective workshops in addition to that. All three groups' workshops/classes were taken by the first author who is fully qualified to instruct in all these subjects. Comparison of conventional mathematics methods and VM methods is shown in the Appendix.

The YP intervention workshops were conducted with students in a comfortable sitting position. The first two are technically Yoga purification exercises (Kriyas), while the third, Sectional Breathing, is closely related to certain Western approaches to improve the quality of breathing. The next three are classic YPs found in classic texts (Hatha YP, Nagendra, 2003) as is the more demanding final exercise, Bhramari Pranayama, in which eyes, ears, and mouth are covered by fingers.

In the VM intervention workshops, standard topics in 11th and 12th grade mathematics syllabus were taught according to standard VM procedures. Table 1 displays representative examples, details of three are set out in the Appendix. The first employs "vertically and crosswise" to solve an example of simultaneous equations. The second simplifies integration of a reciprocal quadratic function (factorizable) using "transpose and apply." The third example offers a multiple choice question on integrating reciprocal quadratic functions that cannot be factorized.

Table 1: Intervention

Yoga Pranayama and breathing exercises (Kriya)	Vedic Mathematics rules and topics taught
Bhastrika-Kriya	One more than one before squaring, cubing
Kapalabhati Kriya	Vertically and crosswise, addition and subtraction, transpose and apply multiplication, determinants, simultaneous equations
Sectional breathing, abdominal breathing, thoracic breathing, upper lobar breathing, full yogic breathing	Proportionately, by alternate elimination and retention, the first by the first and last by the last factorization
Chandra anuloma viloma, surya anuloma viloma pranayama	Paravartya partial fractions, conics
Nadi Shuddi-alternate nostril breathing	Differential calculus
	Integration and quadratic equation
Bhramari	Addition and subtraction, the first by the first and last by the last, by alternate elimination and retention
	Highest common factors

This represents the most difficult kind of problem in this level of mathematics in India since it requires understanding functions such as inverse hyperbolic functions that are less familiar to the student. Even good students incur conceptual problems, time loss, and errors when attempting these problems. In the workshops, VM sutras, "vertically and crosswise," "transpose and apply," and "addition and subtraction," were all separately utilized in demonstrating alternative approaches to solving simultaneous equations, emphasizing the choice now being offered to students. Integration of reciprocal quadratic functions requires closer inspection and use of recommended VM time-saving patterns.

Assessment instruments used

Mindfulness attention awareness scale

The MAAS instrument[29] is a single-factor 15-item questionnaire. Total score on its six-point scale (1 = almost always to 6 = almost never) can vary from 15 to 90, but normal scale score is taken as the average over the 15 items. Higher scores reflect higher levels of dispositional mindfulness. Researchers report MAAS reliability in university samples as 0.82.[29] The instrument has been validated in college, community adults, and cancer patient populations in different studies.[30,31] Mindfulness as measured by the MAAS is held to connect consciousness to emotional regulation, behavior regulation, and well-being.

Nonphysical aggression scale from Pittsburgh youth study

The Nonphysical Aggression Scale from Pittsburgh Youth Study[32,33] measures the nonphysical aggressive behavior of children, validated by a longitudinal study of 1517 inner-city boys in Pittsburgh, Pennsylvania, starting from 1987. The study regularly measured risk factors involved in disruptive, delinquent, drug-related, and antisocial behavior of adolescent and preadolescent boys in the beginning, and on half yearly assessment, and later extended assessments to include the female population.[34,35]

Nonphysical Aggression Scale is 16 items of measuring nonphysical aggressive behaviors, such as arguing, bragging, seeking attention, disobeying parents or teachers, not getting along with others, swearing, and sulking. It has Internal Consistency 0.85 on a sample of 6-, 9-, and 12-year-old males followed into adulthood. Its 3-point scale ranges from 0 = not true to 2 = very true.

Emotion regulation questionnaire

The ERQ[36] consists of 10 items on a 7-point scale (1 = strongly disagree to 7 = strongly agree). It measures two important aspects of emotion such as emotional experience and emotional expression, both pointing to control and management of emotion. Questions concerning positive and negative emotions assess individual differences connected to cognitive reappraisal and expressive suppression. Average

value of Cronbach's alpha is 0.79 for reappraisal and 0.73 for suppression. Test–retest reliability was 0.69 for both the scales. Reappraisal items are nos. 1, 3, 5, 7, 8, 10 and suppression items are numbers 2, 4, 6, 9. Scale scores are obtained by adding response values for each item on that scale.

Statistical analysis

IBM SPSS Statistics for Windows, Version 19.0, manufactured by IBM Corporation, Armonk, NY, was used to analyze data. The data were found to be normally distributed, so preliminary group comparisons were RM ANOVAs with *post hoc* Bonferroni correction for each of the four scales. Since this was found statistically significant, the predata for the three groups were compared and found not to be statistically significantly different on any of the tests. Next, paired sample *t*-tests were used to compare pre–post within group differences, and then group time interaction tests were used to compare differences between experimental and control groups.

Results

Demographic variables and age were not significantly different for the three groups. The RM ANOVAs were statistically significant for the tests of mindfulness, F (2, 240) = 19.88, $P < 0.001$, and aggression, F (2,240) = 14.49, $P < 0.001$, but not for either positive or negative ERQ scales. Experimental results are set out in Tables 2 and 3. Table 2 presents pre- and post-intervention values of the three groups on the four different scales, giving statistical significance of within-group pre–post differences. Table 3 sets out between-group comparisons of Table 2's within-group differences, i.e., group-time interaction effects, giving their significances, as explained in Table 3 caption. Table 2 shows that mindfulness, aggression, and negative emotion regulation changed significantly for the YP group ($P \leq 0.001$ for mindfulness and aggression; $P \leq 0.028$ for negative emotion regulation), while for the VM group, only mindfulness improved significantly, $P \leq 0.001$ [Table 2 and Figure 2], though changes in aggression may have showed a weak trend toward improvement ($P = 0.15$). No group changed significantly on positive emotion regulation. Controls seemed to improve on aggression, $P \leq 0.030$ (paired sample *t*-test) [Table 2 and Figure 3]. Effect sizes (Cohen's d) were for the YP group, 0.93 (mindfulness), 0.78 (aggression), and for the VM group, 0.29 (mindfulness).

Table 3 shows Group-Time interaction differences and significances. Mindfulness and aggression changed significantly more for the YP group than for VM and control groups, $P \leq 0.001$ [Figure 4a and b], but within-group changes on positive and negative emotion regulation scores were not significantly different between the three groups.

Discussion

Reported results are not entirely as hypothesized. The YP group performed best overall on the tests, possibly because the sequence of YP practices settles the mind and may bear some similarity to MBI. The VM group was observed to increase by a small amount in mindfulness with high significance but was not observed to decrease significantly in aggression as had been hypothesized. Increased confidence in

Table 2: Pre- and post-values of the variables

Test	Group								
	Yoga Pranayama (73)			Vedic Mathematics (80)			Controls (90)		
	Pre	Post	*t*	Pre	Post	*t*	Pre	Post	*t*
Mindfulness	57.85±9.45	67.75±11.52***	−8.72	56.50±11.72	60.19±13.56***	−3.92	60.39±10.96	61.53±11.87	−1.23
Aggression	11.64±4.31	8.4±4.03***	7.29	11.53±4.34	11.01±4.55	1.50	11.18±3.96	10.39±4.3*	2.21
Emotion regulation (positive)	27.18±5.77	26.48±6.59	0.62	29.53±5.67	28.73±6.10	1.09	27.64±5.67	27.23±5.37	0.61
Emotion regulation (negatives)	18.77±4.5	17.51±4.88*	2.24	20.25±4.60	19.84±4.58	0.80	18.53±5.28	18.39±5.34	0.30

Table 2 presents mean, SD and significances of within-group changes for the three groups. Significance values are indicated by ***$P \leq 0.001$, *$P \leq 0.05$. SD=Standard deviation

Table 3: Within-group differences and significances of between-group comparisons

Test	Group		
	Yoga Pranayama	Vedic Mathematics	Control
Mindfulness	9.88±9.77***	3.69±8.40***	1.14±8.82***
Aggression	−3.28±3.82***	−0.51±3.16***	−0.79±3.39***
Emotion regulation questionnaire (positive)	−0.44±6.7	−0.8±6.56	−0.41±6.42
Emotion regulation questionnaire (negative)	−1.26±4.79	−0.41±4.62	−0.14±4.6

Table 3 presents group time interactions, i.e., changes in means (post-pre) and their SDs for the three study groups together with the significances between groups. Significance values are indicated by ***$P \leq 0.001$. Those under Vedic Mathematics are significance of differences with the Yoga Pranayama group while those under controls are also significances with the Yoga Pranayama group. For none of the four variables did the differences between the Vedic Mathematics and control groups reach significance. SD=Standard deviation

a single subject, mathematics, may not necessarily translate into decreases in self-reported feelings of aggression, particularly as the learning environment did not change for teaching other subjects, and the learning environment has been found to be a significant factor in stress generation.[37]

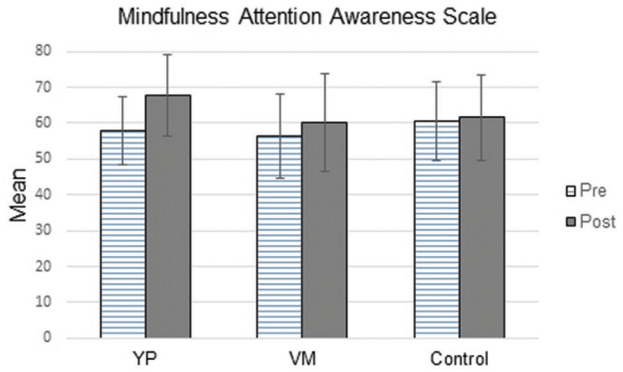

Figure 2: Shows Mindfulness Attention Awareness Scale pre–post mean scores with a significant increase in Yoga Pranayama and Vedic Mathematics ($P \leq 0.001$) groups. All bars and attached error lines represent means ± standard deviations

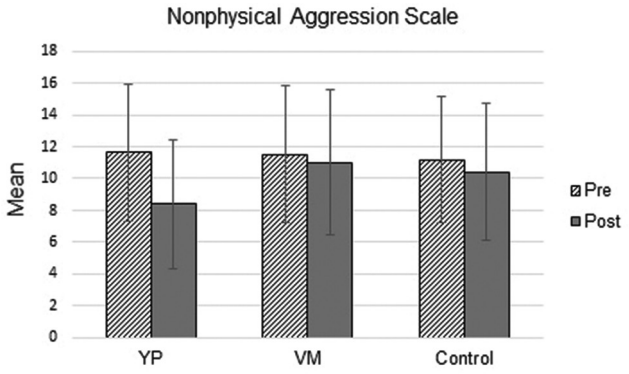

Figure 3: Depicts pre- and post-mean scores of the three study groups on the Nonphysical Aggression Scale from Pittsburgh Youth Study. All bars and attached error lines represent means ± standard deviations. Decreases for Yoga Pranayama (−3.25, $P \leq 0.001$) and Control (−0.79, $P = 0.030$) groups attained reportable significance, $P \leq 0.05$

A possible reason for the observed increase in mindfulness in the VM group may be that giving students choice of how to perform calculations enhances their ability to reflect internally on their own preferences, thus increasing their capacity for a more internally directed orientation of awareness. It can also be argued that adding a fun element to the learning process involving pattern recognition, a right hemisphere activity,[38] may have improved participants' capacity for being in the present moment.[39] Another possible reason is that reductions in mathematics anxiety may make mindfulness easier to maintain.

The YP group improved far more in mindfulness than the other two groups ($P = 0.0001$ in both cases), and alone decreased highly significantly in aggression and significantly on negative emotion regulation. Several studies have reported increases in emotional regulation resulting from mindfulness training.[40] For one group to both increase in a measure of mindfulness and decrease in aggression and negative emotion is consistent with these results. In support of this, Yoga, including nadi-shodana pranayama as used in this study, has been found to be very effective in changing the levels of key endocrine molecules associated with stress such as epinephrine and norepinephrine.[41] This may explain its effectiveness in decreasing self-reported aggression on the Nonphysical Aggression Scale from Pittsburgh Youth Study.

The observed effect of YP on mindfulness is important. Although the practice is not specifically designed to increase mindfulness, it is extremely calming and centering for participants' awareness, and evidently increases mindfulness as a beneficial side effect.[8] Further studies of this could prove helpful.

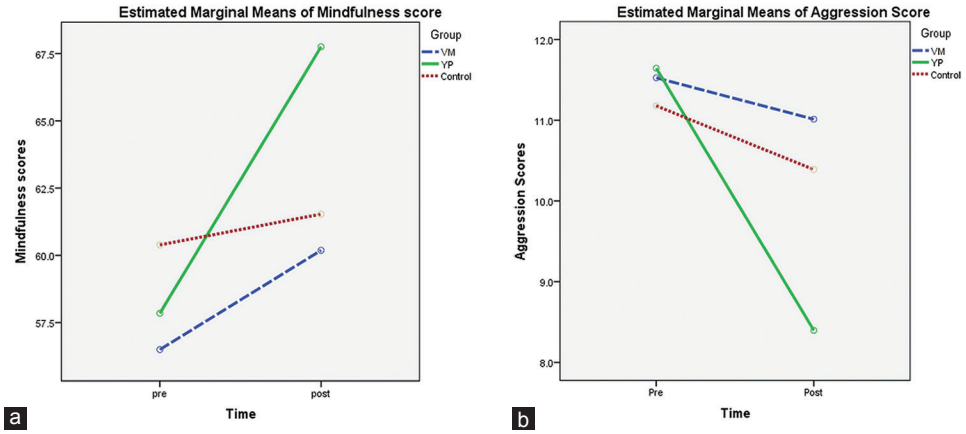

Figure 4: (a) Group-time interaction effects on mindfulness scores. At time 1, i.e., pre, all the three groups are not significantly different from each other on mean mindfulness scores. At time 2, i.e., post, Yoga Pranayama group is significantly higher on mean mindfulness score from Vedic Mathematics ($P = 0.001$) and control ($P = 0.005$) groups. (b) Group-time interaction effects on Nonphysical Aggression scale. At time 1, i.e., pre, all the three groups are not significantly different from each other on mean aggression scores. At time 2, i.e., post, Yoga Pranayama groups mean aggression score is significantly lower from Vedic Mathematics ($P = 0.001$) and control ($P = 0.011$) groups

Yogic *Kapalabhati Kriya* washes away carbon dioxide and increases oxygen concentration, also revitalizes the functions of brain cells. *Nāḍī Śuddhi* brings sympathetic and parasympathetic balance in the nervous system and balance in anabolic and catabolic processes which would lead to clarity of mind and concentration.[17] Hence, this could be the reason to find the overall improvement in YP group.

In contrast, controls' observed decrease in aggression seems anomalous. When 12 group comparisons are made in a single study, one change reaching $P < 0.05$ by chance is not unusual.

As regards possible connections between MAAS measured mindfulness and emotion and behavior regulation, we performed various correlations between premeasurements of our 243 participants in a *post hoc* analysis. Correlations between mindfulness and aggression reached significance, Pearson's $r = -0.45$, $P < 0.0001$, for prevalues, with similar values for postvalues, while those between prevalues of mindfulness and negative ERQ were $r = -0.214$, $P = 0.001$, while postvalues showed $r = -0.236$, $P = 0.001$. While the first is clearly expected, the second result is interesting in that those with higher scores on mindfulness felt less need to hide negative feelings, possibly indicating that their general levels of negativity were less and equally that negative feelings may block mindful awareness.[42] The same might also be said about the first correlation, those with high levels of outward aggression, presumably originating in internal frustration, may be less capable of being in present moment states of mindfulness.[12]

However, a similar analysis of correlations between the ERQ positive and ERQ negative scales yielded extraordinary results: Pearson's $r = 0.24$, $P < 0.0002$, prevalues, and $r = 0.35$, $P < 0.0001$ postvalues. Positive correlations between supposedly independent scales, even correlations of this magnitude, are not to be expected. The interpretation of this correlation is difficult but may mean that the test needs revalidation in India, where English may not be English speakers' mother tongue.

The strengths of the study include the number of participants for pre–post within group changes and intergroup comparisons. Moreover, it specifically supports the idea that YP can improve participants' quality of mindfulness[8] and help in students' management of aggression issues.[23] The main weakness was the assignment of participants to groups by an arbitrary choice of which class took which intervention, rather than by a fully randomized assignment to different groups. Although the latter would have made the study technically superior, each class was naturally heterogeneous and had similar baseline sociodemographic characteristics; there is no reason to believe that it would have changed the overall findings and conclusions.

Results of the study were sufficiently promising to encourage further research, particularly in light of the measurements on mathematics anxiety and other variables (submitted for publication). It is hoped that funds for larger, fully randomized studies will be forthcoming.

Conclusions

While VM has been found highly effective in enhancing 12th grade exam results, it seems less effective on variables reported in this study. YP techniques, on the other hand, could be useful in schools and preuniversity colleges to produce more settled states of mind such as those associated with mindfulness and also to reduce symptoms of aggression that seem to result from examination pressures during the 12th grade year of high school/ preuniversity college when such stressors are at their peak.

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Conflicts of interest

There are no conflicts of interest.

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ORIGINAL ARTICLE

Impact of pranayama and Vedic Mathematics on math anxiety and cognitive skills

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ABSTRACT

Context: Many children have low self-confidence in mathematics, leading to math anxiety, disturbed cognitive skills, and reduction of the quality of their educational experience.

Aims: This study aimed to compare methods of reducing such anxiety and improving cognitive skills using pranayama; and second, introducing pattern recognition in problem solving, using methods of Vedic Mathematics. These methods were chosen because pranayamas are well-established, standardized means of anxiety reduction for any stressful condition, offering a precise standard for comparison, while, Vedic Mathematics shortens and facilitates calculations.

Settings and Design: The study design was a randomized controlled trial with three groups: Yoga pranayama (YP), Vedic Mathematics (VM), and controls (CG) taking 12th grade students from a private preuniversity college in India.

Method: Intervention was 15 days each of 30 min daily instruction in either selected YP or VM for the two experimental groups. All the three groups received conventional math training every day. Exclusion criteria were major psychological problems. Assessments used the Mathematics Anxiety Rating Scale Revised and Children's Cognitive Assessment Questionnaire.

Statistical Analysis Used: SPSS 19.0 was used for statistical analysis.

Results: The experimental groups improved on all subscales of both tests, $p < 0.001$: the VM group improving more on the first test and the pranayama group performing better on the second test. Controls showed no improvements.

Conclusion: Introducing pranayama and VM methods as teaching aids would improve cognitive skills and reduce math anxiety and offer a means to improve examination results, as later demonstrated.

Key Words: Cognitive skills, math anxiety, pattern recognition, pranayama, Vedic Mathematics

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INTRODUCTION

Many children have less interest in mathematics (Frenzel, Goetz, Pekrun, & Watt, 2010), and find learning mathematics very difficult. Why this is may not be clear, because many children find well-presented mathematical ideas inspiring (Hohenwarter, Hohenwarter, & Lavicza, 2008; Tatar, 2013). Demands of science and mathematics can turn school into an unpleasant experience (Kihwele, 2014). Anxiety caused by daily mathematics lessons starts in elementary school (Ramirez, Gunderson, Levine, & Beilock, 2013) and becomes a dominant feature of their school experience (Maloney, Risko, Ansari, & Fugelsang, 2010), causing math anxiety (Taylor & Fraser, 2013) and leading to poor performance in mathematics. A specific anxiety rating scale

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for math anxiety developed by Richardson & Suinn (1972) was revised and validated (Plake & Parker, 1982). One problem it causes is decrease in working memory (Maloney et al., 2010), a skill important for performing calculations in class exercises, tests, and examinations (Ashcraft & Krause, 2007). Of many papers on math anxiety (Ashcraft & Krause, 2007; Ashcraft & Moore, 2009; Maloney & Beilock, 2012; Wang et al., 2014), few show how to reduce it (Bellinger, DeCaro, & Ralston, 2015; Brunyé et al., 2013).

How to remedy these problems? This study compares two methods of reducing math anxiety and improving cognitive skills: Vedic Mathematics (VM), a system offering students choice of ways to carry out calculations (Ismail & Sivasubramniam, 2010), and yoga pranayama (YP), a well-researched means of anxiety reduction (Khalsa, Hickey-Schultz, Cohen, Steiner & Cope, 2012; Nemati, 2013; Sharma & Haider, 2013) and benchmark for doing so.

Yoga Pranayama

The first method investigated to reduce student's overall anxiety was YP (Cramer, Lauche, Langhorst, & Dobos, 2016; Goldstein et al., 2016), already well researched at many different institutions (Cramer, Lauche, & Dobos, 2014) and shown to be highly effective against anxiety (Varambally & Gangadhar, 2016; Uebelacker & Broughton, 2016).

Traditionally, pranayama (Nagendra, 2005) is used as preparation for meditation (Brown & Gerbarg, 2009) because it has a delightful settling influence on mind and body, while at the same time enlivening certain levels of "subtle energy" within the tissues (Sharma, Hankey, Meenakshy, & Nagendra, 2014). Its settling influence has been much studied, including test anxiety reduction, test performance (Nemati, 2013), perceived stress reduction, and cardiovascular and respiratory parameters (Bhavanani, Raj, Ramanathan, & Trakroo, 2016; Sharma et al., 2013).

Universally, high levels of stress, elevating levels of disease, make application of pranayama to decrease the effects of stressful situations an acute need of our times. Learning its practice in school offers children a life skill with lifelong benefits. It was of central interest here because competitive examination systems providing elimination procedures for those entering professional education have put new pressures on schoolchildren (Kadapatti & Vijayalaxmi, 2012). Also, more countries today are seeking to become knowledge-based societies (Gilbert, 2005), offering citizens more interesting work than drudgery of employment in mines and factories. However, some argue that examination-oriented education systems pressure children unnecessarily.

Introducing children to stress-reducing techniques of yoga offers great potential benefit. By steadying the breathing process, pranayama steadies the mind itself. Everything passing through the mind can be "seen" and understood more clearly (Jerath & Barnes, 2009). Conversely, when a person performs a steadying series of yoga breathings, their emotions are steadied (Gilbert, 1999), negative thoughts tend to decrease (Arch & Craske, 2006), and their thinking patterns become clearer and more positive. Problem-solving abilities and mental efficiency improve (Sharma et al., 2014). YP also promotes positive health among adolescents (Singh, 2015).

Vedic Mathematics

VM gives students a choice of method to solve problems by selecting specific patterns of calculation (Muehlman, 1998). It shortens many calculations, directly improving examination results. Previously, mediocre students start scoring 90% or higher. Various researchers have demonstrated the intuitive and holistic nature of VM (Muehlman, 1998).

VM (Tirthaji Maharaja & Agarwala, 1992) seems to have been developed by Bharathi Krishna Tirtha (1884–1960) and by Shankaracharya of Puri, who said that it effectively formed an appendix to Atharva Veda. Previously, a teacher of high school mathematics demonstrated many applications at that level which have since been greatly expanded (Nicholas, Williams, & Pickles, 2010).

The Shankaracharya's methods prove popular with children learning them (Ismail & Sivasubramniam, 2010). They develop abilities to visualize patterns of calculation for solving problems. Imagining hidden pictorial or algebraic patterns leads to enjoying the process (Zazkis & Liljedahk, 2002). Performing calculations becomes more like a game.

Professional mathematicians use similar powers of mental cognition in understanding and creating mathematics. VM methods have been applied professionally, for example, to shorten algorithms for multiplier circuits and decrease chip areas (Anjana, Pradeep, & Samuel, 2015; Bansal & Madhu, 2016).

This led to the choice of tests employed in this study; the Mathematics Anxiety Rating Scale-Revised (MARS-R) aims to assess benefits of learning VM, while the Children's Cognitive Assessment Questionnaire (CCAQ) was chosen to demonstrate benefits of the chosen sequence of pranayamas and related yoga breathing as summarized in Table 1.

METHOD

Participants

A total of 168 students, aged 17.0–18.5 years, studying in 12th standard at a Pre-University College in Chikkmagaluru,

Table 1: Group comparison–Children's Cognitive Assessment Questionnaire

	VM	YP	Control
Negative evaluation	−0.88±1.34*	−1.63±2.47*	−0.38±2.16
Off task	−1.23±1.79**	−1.63±1.9**	−0.48±2.16
Positive evaluation	1.00±1.75*	1.14±1.76*	0.36±1.85
On task	0.48±1.73	0.49±1.36	0.24±1.27

*$p<0.05$, **$p<0.01$. Table 1 shows pre-post differences (as mean±SD) for the three groups on Children's Cognitive Assessment questionnaire. As expected, controls were not significantly changed, while both experimental groups improved significantly compared to controls. Between experimental groups YP show greater improvements than VM. VM: Vedic Maths; YP: Yoga pranayama; SD: Standard deviation

Karnataka, India, were randomly assigned to: YP (59 students, 34 male, 25 female), VM (59 students, 16 male, 43 female), and controls (CG – 50 students, 22 male, 28 female).

Design

The three groups employed pre-post randomized controlled design [Figure 1]. Randomization used an online random number generator (Psychic Science, n.d.). G*Power analysis on a pilot study yielded $n = 23$.

Informed consent

The study purpose and design were explained to parents/guardians who signed informed consent forms.

Interventions

Students in the experimental groups attended workshops lasting 30 min/day for 15 days during their regular mathematics classroom periods. The YP group received instruction in yoga breathing while the VM group received instruction and exercises in VM. Controls continued their usual maths classwork during the same classroom periods. Thirty minutes daily instruction was given to all the three groups at different times by the first author who is expert in YP, VM, and conventional mathematics teaching methods. The YP and VM groups also attended conventional mathematics classes after the 30 min intervention class.

The YP intervention consisted of a sequence of yoga breathing listed in the right column of Table 2. The first two (Kapalabhati and Bhastrika) are yoga kriyas and cleansing techniques, the third is deep breathing technique, while the last three are forms of pranayama. Each technique was first demonstrated, and then the class imitated the demonstrator, each member being carefully corrected for mistakes. After mastery of the first technique, instruction moved to the second technique, etc., until all were confident in performing the techniques in sequence. In each workshop, verbal instructions were given to start each technique and students with difficulties were helped. After each allotted 5 min time period, the group began performance of the next technique. Each workshop ended with Bhramari pranayama, the 6th technique listed in Table 2 (right column).

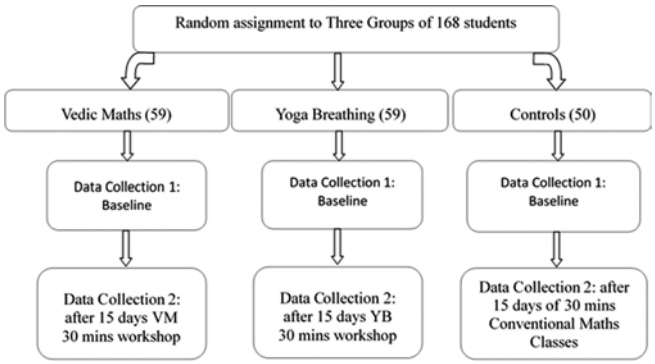

Figure 1: Study design. Participants were divided randomly by a random number generator into three groups: Vedic Mathematics, yogic breathing, and controls. Baseline data were collected and respective interventions were administered for 15 days. Postdata collection was carried out after the intervention

The VM intervention comprised instruction in 12th standard mathematics, taught by standard procedures for VM instruction. Examples are given in Table 2, with details of three explained in Appendix, for example, solutions to simultaneous equations were demonstrated using VM sutras, "vertically and crosswise," "transpose and apply," and "addition and subtraction," offering alternative strategies to solve equations related to specific examples. Example 1 solves two simultaneous equations using "vertically and crosswise." Example 2 demonstrates the use of "transpose and apply" to simplify integration of the reciprocal of a factorable quadratic function. Both problems cause less gifted students conceptual problems, time loss, and errors. Example 3 presents a multiple choice question on integration of nonfactorizable quadratic functions, the most difficult problem in Indian preuniversity maths, requiring understanding functions less familiar to the student [Appendix 1].

These examples show how VM methods shorten 12th grade maths calculations used in differential and integral calculus, coordinate geometry, algebra, trigonometry, vectors, and 3D geometry. The above topics were taught to all the three groups participating in

Table 2: Details of two Interventions

Topics and Vedic Maths sutras used	Yoga breathing/ pranayama
1. Topics: Simultaneous Equations, Determinants, Multiplication Sutras used: Vertically and Crosswise, Addition and Subtraction, Transpose and Apply.	1. Kapala Bhati – Kriya
2. Topics: Partial Fractions, Conics Sutra Used: Transpose and Apply.	2. Bhastrika - Kriya
3. Topics: Quadratic Equation, Integration, Sutra used: Differential Calculus.	3. Sectional Breathing Abdominal breathing, Thoracic breathing, Upper lobar breathing, Full yogic breathing
4. Topics: Squaring, Cubing Sutra used: One more than one before.	4. Surya anuloma, Chandra viloma (single nostril breathing) pranayamas
5. Topics: Factorization Sutras used: Proportionately, By alternate elimination and retention, The first by the first and last by the last.	5. Nadi Shuddi (anuloma viloma) pranayama – Alternate Nostril breathing
6. Topics: Highest common factors Sutras used: Addition and subtraction, The first by the first and last by the last, By alternate elimination and retention.	6. Bhramari pranayama

the study, but only the VM group learned to solve problems by VM procedures.

Assessments

Mathematics Anxiety Rating Scale-Revised (Plake & Parker, 1982)

This 24-item instrument is designed to measure anxiety incurred in maths and statistics courses. It is a revised version of a 98-item scale by Richardson & Suinn (1972), and is more focused on situation-specific (state) anxiety, general (trait) anxiety, and test anxiety. It contains two subscales: learning mathematics anxiety (LMA) concerning processes of learning of maths and statistics and evaluation maths anxiety (EMA) measuring anxiety from maths and statistics tests. LMA plus EMA form the total maths anxiety (TMA).

Scoring: Respondents rate each item on a 5-point scale from "low" to "high anxiety."

Scores are the sum of item ratings, ranging from 24 to 120 for the total scale.

Children's Cognitive Assessment Questionnaire (Zatz & Chassin, 1983)

This 40-item instrument measures self-defeating and self-enhancing cognitions associated with test anxiety. It focuses on negative self-evaluations and positive self-evaluations, reflecting self-defeating and self-enhancing cognitions. It also assesses distracting, "off-task thoughts," and "on-task thoughts," focusing attention on task. These four constitute CCAQ subscales.

Scoring: Each item is answered true or false. Scores on the four subscales are the number of items answered "true," ranging from 0 to 10. The first two subscales more reflect thoughts associated with test anxiety, while the last two subscales reflect less test anxiety.

Data analysis

IBM SPSS Statistics for Windows, Version 19.0, manufactured by IBM Corporation, Armonk, NY (IBM Corp., 2010) software was used, and Kruskal–Wallis, Mann–Whitney, and Wilcoxon tests were also used for data analysis.

RESULTS

Seven students in the VM group and eight in YP group failed to give postintervention data, and were listed as dropouts. Data were therefore analyzed for the remaining 52 students in VM, 51 in YP group, and 50 in CG. Baseline demographic data were not significantly different between the three groups.

Test results are presented in Tables 1 and 3-5. Table 3 presents means and standard deviations of the scores on MARS-R for the three groups, pre- and postinterventions, while Table 4 and Figure 2 summarize pre-post differences, giving statistical significances of differences between experimental and CGs. The VM group showed consistent improvements on both LMA and EMA subscales, $p < 0.001$, while the YP group showed consistent improvements on both subscales at $p < 0.01$. Controls showed no change in scores.

For CCAQ results, Table 5 presents pre-post values of means and standard deviations for the three groups, pre- and postintervention period. As hypothesized, both experimental groups showed significant pre-post differences, $p < 0.001$. Significance was less for the On Task subscale, where the YP group attained $p < 0.05$, while the difference for the VM group was only $p = 0.06$ only, showing a trend; interestingly, values for controls improved on every scale, but did not reach significance on any.

Table 1 and Figure 3 compare the groups' pre-post differences showing that relative improvements between CG and the YP groups were significant for the first three subscales, reaching $p < 0.01$ for the Off Task subscale and $p < 0.05$ for negative and

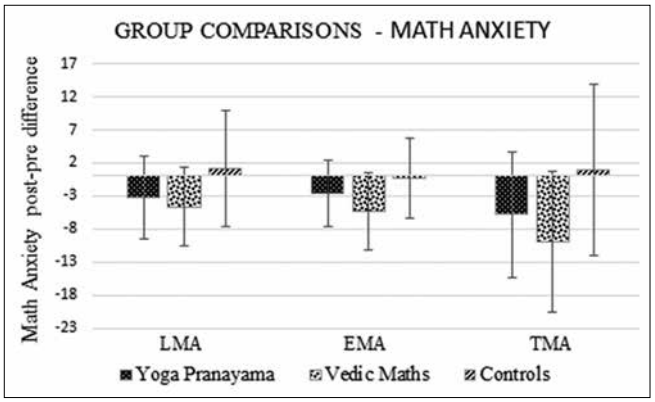

Figure 2: Math anxiety post-pre mean score comparisons for yoga pranayama, Vedic Mathematics, and controls. Math anxiety post-pre difference comparisons for the three study groups from Mathematics Anxiety Rating Scale-Revised. Decrease in math anxiety for yoga pranayama and Vedic Mathematics is significant as compared to controls; $p < 0.01$ and $p < 0.001$, respectively. All bars and attached error lines represent means ± standard deviations

Table 3: Mathematics Anxiety Rating Scale – revised results

	VM		YP		Control	
	Pre	Post	Pre	Post	Pre	Post
LMA	33.46±9.64	29.40±10.33***	32.74±9.88	29.26±9.01***	34.92±10.16	36.08±10.33
EMA	22.84±7.28	17.57±7.35***	20.60±6.78	17.57±6.2***	20.90±6.2	20.60±6.42
TMA	56.30±15.74	46.97±16.89***	53.33±15.83	46.83±14.1***	55.82±15.26	56.68±15.32

***$p<0.001$. Table 3 presents pre and post (as mean±SD) of VM, YP, and control groups on MARS-R. The differences for both experimental groups were all highly significant, $p<0.001$, while controls showed essentially no change at all. LMA: Learning mathematics anxiety; EMA: Evaluation mathematics anxiety; TMA: Total mathematics anxiety; SD: Standard deviation; MARS-R: Mathematics Anxiety Rating Scale-Revised; VM: Vedic Mathematics; YP: Yoga pranayama

positive evaluation subscales, but not for the fourth subscale, On Task. Pre-post differences were significantly different for positive evaluation between VM and CGs ($p < 0.05$).

DISCUSSION

Results confirm experimental hypotheses with good statistical significance, math anxiety reduces most in the VM group (Cohen's d = 0.57 for TMA in VM), and seemingly less in the YP group, though between-group differences were not significant. Scores on CCAQ improved most in the YP group, less in the VM group, but not in CG – with a similar caveat (Cohen's d varies from 0.35 to 0.95 for various CCAQ parameters for YP). The immediate scientific question is why should such results obtain?

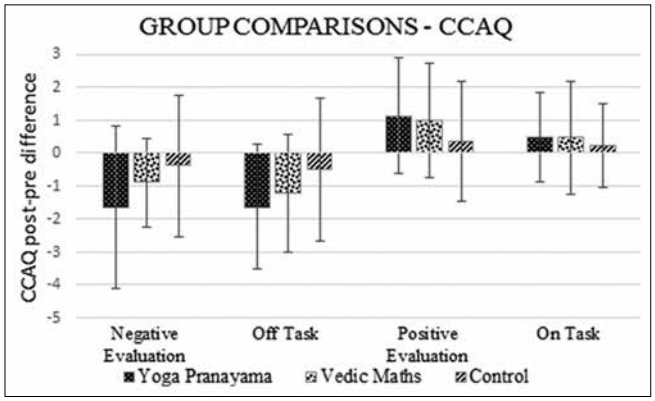

Figure 3: Children's Cognitive Assessment Questionnaire post-pre mean score comparisons for yoga pranayama, Vedic Mathematics, and controls. Comparing Children's Cognitive Assessment Questionnaire post-pre differences among the three groups. Yoga pranayama group shows significant reduction in negative evaluation ($p < 0.05$) and Off Task thoughts ($p < 0.01$) as compared to controls. Yoga pranayama and Vedic Mathematics groups improved significantly in positive evaluation ($p < 0.05$) as compared to controls. All bars and attached error lines represent means ± standard deviations

Table 4: Comparison of pre-post differences between experimental and control groups - MARS-R

	YP	VM	CG
LMA	−3.22±6.26**	−4.62±6.01***	1.16±8.71
EMA	−2.61±4.98**	−5.35±5.77***	−0.30±6.06
TMA	−5.82±9.56**	−9.96±10.68***	0.86±12.95

**$p<0.01$, ***$p<0.001$. Table 4 respresents the pre-post differences (as mean±SD) for the three groups, together with the statistical significance of between-group differences, on MARS-R. The controls were unchanged, while both experimental groups improved significantly, with VM improving more than YP. VM: Vedic Mathematics; YP: Yoga pranayama; CG: Control group; SD: Standard deviation; LMA: Learning mathematics anxiety; EMA: Evaluation mathematics anxiety; TMA: Total mathematics anxiety

Systematic reviews of randomized controlled trials (RCTs) of yoga provide much evidence for benefits of YP for anxiety (Sharma & Haider, 2013; Weaver & Darragh, 2015). Changes observed in the YP group are consistent with such predictions and G*Power analysis. Changes observed in the VM group may be attributed to the intervention. Similarly, studies comparing yogic practices to eyes-closed rest obtain different results for experimental and CGs: eyes-closed rest showing little change (Travis & Wallace, 1999). Positive effects observed in the YP group are therefore due to the intervention.

Reasons for using YP comparison group may still require comment. YP practices can be taken as a benchmark with which to compare other methods of anxiety reduction. They are effective for any kind of stressful condition. Evaluation of their comparative ability to reduce math anxiety is therefore relevant.

This study represents the first full study of effects of using the VM approach to maths teaching, though a single case study has recently been published (Pagedar, 2015). Many studies concern effects of regular practice of yoga in the classroom (Ferreira-Vorkapic et al., 2015). In India, introducing yogic practices is intended to improve the quality of life of schoolchildren, as well as, help decreasing anxiety and depression generated by emphasis on exam performance. Any study providing evidence for benefits to schoolchildren of particular yoga practices is therefore of potential value.

Another angle of investigation is provided by a study of 1345 Filipino engineering students aged 15–25, which showed that, when learning trigonometry, anxiety measured by the Academic Emotion Questionnaire – Mathematics correlates negatively with positive emotions, pride, and enjoyment (Villavicencio & Bernardo, 2016). Findings from our data are parallel to those Spearman's rho between the three subscales of MARS-R and the four subscales of CCAQ ranged from $\rho = 0.273$ to $\rho = 0.450$, with all highly significant ($p < 0.0001$). Although the correlations may be expected, since both tests concern quality of emotion experienced by participants, it is of value to see the extent of the correlations.

Table 5: Children's Cognitive Assessment Questionnaire - results

	VM		YP		CG	
	Pre	Post	Pre	Post	Pre	Post
Negative evaluation	3.02±2.0	2.06±1.76***	3.60±2.53	1.93±1.76***	3.02±2.16	2.64±2.38
Off task	4.88±2.58	3.58±2.53***	4.51±1.91	2.93±1.50***	4.92±2.25	4.44±2.27
Positive evaluation	7.43±1.91	8.42±1.69***	6.88±2.34	8.00±1.86***	7.00±2.21	7.36±2.04
On task	7.67±1.73	8.36±1.74	7.77±1.54	8.27±1.43*	7.68±1.8	7.92±1.75

*$p<0.05$, ***$p<0.001$. Table 5 shows the pre and post means and standard deviations for VM, YP, and CGs on the CCAQ. Differences for both experimental groups were highly significant, $p<0.001$, except for the On task subscale, where only YP reached $p<0.05$. Controls showed no significant difference on any subscale. CCAQ: Children's Cognitive Assessment Questionnaire; VM: Vedic Mathematics; YP: Yoga pranayama; CG: Control group

CONCLUSION

This study obtained good statistical significance in all subscales of both tests except the fourth subscale of CCAQ, On Task. These observed pre-post improvements were significant at $p < 0.05$, but did not reach significance between groups. Improvements on other subscales for both VM and YP groups suggest considering VM as a potential teaching aid and yogic breathing as an activity to improve cognitive skills in schoolchildren.

Strengths

The study was a RCT with 59 in VM, 59 in YP, and 50 in CGs. It obtained significant results on all subscales of both tests except CCAQ's 4th subscale.

Weaknesses

The first author is an experienced teacher of both VM and YP. Whether reported results depend on teacher's personal qualities may require further study. However, he also conducted mathematics classes for controls; their lack of improvement tends to discount teacher's personal qualities as the cause of improvements in experimental groups.

Future research

Being the first quantitative study of the effects of VM on math anxiety, results need to be verified by further research. Follow-up studies including more test variables have been planned.

The first author introduced VM as a means to improve mindfulness (Shastri, Hankey, Sharma, & Patra, 2017) and student performance on final-year professional examinations. A 6-year assessment is being made of examination results at the school where the study was performed.

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Conflicts of interest

There are no conflicts of interest.

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APPENDIX

Appendix I

Example 1: Simultaneous equations. Students often solve simultaneous equations in problems on "coordinate geometry," "algebra', "calculus" and other chapters in maths and physics. Conventional methods take more time but finding values of x and y is really time saving using VM methods which show patterns.

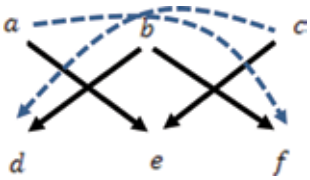
Find values of x and y if $3x+5y=13$ and $4x+7y=18$

$3x+5y=13$

$4x+7y=18$

VM method: $x=\dfrac{5.18-13.7}{5.4-7.3}=1,$ $y=\dfrac{13.4-18.3}{5.4-7.3}=2,$

Multiplication pattern shown using the Vedic math procedure, vertically and crosswise.



$ax+by=c$

$dx+ey=f$

$x=\dfrac{bf-ce}{bd-ae},$ $y=\dfrac{cd-af}{bd-ae}$

The Vedic mathematics procedure enables students to find either x or y mentally, depending on which looks easier, and then substitute it to find the other value. The conventional method of calculating their values is as follows:

$3x+5y=13$ (1a)

$4x+7y=18$ (2a)

Multiplying (1a) by 4 and (2a) by 3 we obtain,

$4x+7y=18$ (1b)

$12x+20y=52$ (2b)

Subtracting (2b) from (1b) gives $y = 2$ and substituting this in either equation yields $x = 1$. Note the labor-saving advantages of the Vedic Mathematics approach.

Example 2: $\int\dfrac{1}{x^2+5x+6}dx=\int\dfrac{1}{(x+2)(x+3)}dx=\int\dfrac{A}{(x+2)}dx+\int\dfrac{B}{(x+3)}dx$

Vedic Mathematics suggests an application of the procedure, "Transpose and Apply," as follows.

First let $x=-2$ $(\because x+2=0)$ in LHS of the equation, giving $\dfrac{1}{-2+3}=1$ which is A.

Next let $x=-3$ $(\because x+3=0)$ in LHS of the equation, giving $\dfrac{1}{-3+2}=-1$ for B.

Finally, integrate obtaining $I=\log(x+2)-\log(x+3)+C$. Note how using this procedure converts the solution to the problem into a one-line mental calculation.

The laborious conventional method requires multiplying out the polynomial fraction:

$\int\dfrac{1}{(x+2)(x+3)}=\int\dfrac{A}{(x+2)}+\int\dfrac{B}{(x+3)}$

Consider $\dfrac{1}{(x+2)(x+3)}=\dfrac{A}{(x+2)}+\dfrac{B}{(x+3)}$

$$\frac{A(x+3)+B(x+2)}{(x+2)(x+3)}$$

$$\Rightarrow 1 = A(x+3)+B(x+2)$$

$$\Rightarrow 1 = Ax+3A+Bx+2B$$

By equating coefficients of and constant terms.

$0 = A+B$ and $1 = 3A+2B$ and solving them we get $A = 1 \text{and} B = -1.$

Now, substitute values of A and B and finally integrate to get

$$I = \log(x+2) - \log(x+3) + C.$$

Example 3: Choose the correct option for the integral $\int \frac{dx}{9x^2 - 12x + 8} =$

(a) $\frac{1}{6}\tan^{-1}\frac{3x+2}{2}$ (b) $\frac{1}{6}\log\frac{3x-2}{3x+2}$ (c) $\frac{1}{6}\sin^{-1}\frac{3x+2}{2}$ (d) $\frac{1}{6}\tan^{-1}\frac{3x-2}{2}$

The procedure evolved from Vedic Mathematics methods for this kind of problem is as follows:

First, observe the sign of the discriminant $=144-288=-144<0$, negative; next the sign of the coefficient of the square term, $a=9>0$, positive; last write down the derivative $f'(x)=18x-12$, all of which are easily done mentally and it is a part of students' earlier training in quadratic equations.

The final answer, $\int \frac{dx}{9x^2-12x+8} = \frac{2}{\sqrt{144}}\tan^{-1}\frac{18x-12}{12} = \frac{1}{6}\tan^{-1}\frac{3x-2}{2}$

is obtained using the rule $I = \int \frac{dx}{ax^2+bx+c} = \begin{cases} \frac{1}{\sqrt{D}}\log\left[\frac{f'-\sqrt{D}}{f'+\sqrt{D}}\right], & a>0, D>0 \\ \frac{1}{\sqrt{D}}\log\left[\frac{\sqrt{D}-f'}{\sqrt{D}+f'}\right], & a<0, D>0 \\ \frac{2}{\sqrt{|D|}}\tan^{-1}\left(\frac{f'}{\sqrt{|D|}}\right), & a>0, D<0 \\ \frac{2}{f'}, & D=0 \end{cases}$

In this case, $I = \frac{2}{\sqrt{|D|}}\tan^{-1}\left(\frac{f'}{\sqrt{|D|}}\right) because\, a>0, D<0$

Students trained to observe the signs of the discriminant and the coefficient of x^2 can simply pick the correct answer from among the four options not bothering with detailed calculations, rather performing a quick mental calculation. Answering such a multiple choice question quickly is fun, especially as it obviates the need for laborious algebraic paper and pencil work of the conventional maths method illustrated below.

$$I = \int \frac{dx}{9x^2-12x+8}$$

$$= \int \frac{dx}{9\left\{x^2 - \frac{12}{9}x + \frac{8}{9}\right\}}$$

$$= \frac{1}{9}\int \frac{dx}{\left\{x^2 - \frac{4}{3}x + \frac{8}{9}\right\}}$$

$$= \frac{1}{9}\int \frac{dx}{\left\{x^2 - 2\left(\frac{2}{3}\right)x + \frac{4}{9} - \frac{4}{9} + \frac{8}{9}\right\}}$$

$$= \frac{1}{9}\int \frac{dx}{\left(x - \frac{2}{3}\right)^2 + \left(\frac{2}{3}\right)^2}$$

On other hand, students who were trained only in conventional mathematics textbook teaching, had to choose one of the following forms:

$$1)\int \frac{1}{x^2 - a^2}dx = \frac{1}{2a}log\left|\frac{x-a}{x+a}\right| + c \qquad 2)\int \frac{1}{a^2 - x^2}dx = \frac{1}{2a}log\left|\frac{a+x}{a-x}\right| + c$$

$$3)\int \frac{1}{a^2 + x^2}dx = \frac{1}{a}tan^{-1}\left(\frac{x}{a}\right) + c$$ which are standard formulae to be memorized.

So, $$I = \frac{1}{9}\frac{1}{\left(\frac{2}{3}\right)}\tan^{-1}\frac{x - \frac{2}{3}}{\frac{2}{3}}$$

$$= \frac{1}{6}\tan^{-1}\frac{3x-2}{2}$$

Note that Vedic Mathematics-associated rules are slightly modified forms of the above rules, obtained using the derivative $f'(x) = \pm\sqrt{D}$ as discussed in the Shankaracharya's original Vedic Mathematics text. Here, the rule named as "differential calculus" has been applied to choose the right pattern related to quadratic equations.