 J Communication, 7(2): 296-303 (2016)

Investigating the Impact of E-Learning Support Material on First Year Engineering Students' Mathematics Learning

Noor Ally, Deonarain Brijlall and Adhir Maharaj

Department of Mathematics, Durban University of Technology, South Africa

KEYWORDS Educational Attainment. Quasi-experiment. Sustainable Learning. Education Institutions

ABSTRACT Addressing first year engineering students' basic mathematical competencies have become a prime focus for many higher education institutions in South Africa. Improving these mathematical competences early during the students' studies is an onerous task. This paper reports on an e-interaction of first year engineering students in mathematics. The findings of the research suggested that the design and implementation of e-learning content could be used to assist students in improving their basic mathematical skills. Within the domain of sustainable learning, the educational attainment is possible by managing an e-learning environment effectively.

INTRODUCTION

The poor performance in mathematics by pupils who exit school at grade twelve is of serious concern in South Africa (Bansilal et al. 2014; Brijlall 2014; Brijlall and Maharaj 2014). An added concern for teaching staff from tertiary institutions is how to address this low performance in mathematics when these school leavers enter the universities (Brijlall and Maharaj 2015; Ndlovu and Brijlall 2015). Ally et al. (2015) have found that e-learning is one way in which this concern could be addressed. These researchers, who work in a department that services other departments, were granted funding by their university to explore the successes and weaknesses of e-learning. For this paper, the researchers explored e-learning with students from the engineering faculty. The exploration was called "The Mathematics Pathfinder Project". The first part of this project was to explore whether e-learning was sustainable. That aim was interrogated by considering a framework for sustainable learning. This interrogation led to a report (Ally et al. 2015). In this report the researchers found that previous study findings, the availability of e-learning resources and the analysis of data all satisfy the demands of the three domains of sustainable learning. With these findings the researchers deduced that e-learning can be adopted as a sustainable tool to communicate effective mathematics learning. Once the researchers were convinced that e-learning would be a sustainable mechanism to address the mathematics gaps of first year engineering students, they now investigate the effect of e-learning in addressing these gaps. With this investigation in mind the researchers asked whether e-learning support materials could make a difference in the performance of engineering students in mathematics. To unpack this question the researchers enquired: *What can a quasi-experiment reveal about the use of e-learning support materials serving to sustain the academic performance of at-risk first year engineering students?* To answer this question and for the sake of uniformity the researchers adopted the same conceptual framework they used in the first part of the study by Ally et al. (2015).

Address for correspondence:
Deonarain Brijlall
Professor
37, Halpin Avenue,
Reservoir Hills 4091,
South Africa
Telephone: 031 3532126,
E-mail: deonarainb@dut.ac.za

Research Framework

The researchers describe a framework for research, which they found useful. For all the papers emanating from the Pathfinder project, the researchers adapted the research framework formulated by Asiala et al. (1997). This framework has been effectively adapted in many other South African studies (Ally et al. 2015; Brijlall and Maharaj 2009, 2015; Brijlall et al. 2011; Brijlall and Ndlovu 2013; Ndlovu and Brijlall 2015). From this framework the researchers found how the underlying structure of this study was conceptualized within this framework. For the theoretical analysis they employed the three domains of sustainable e-learning. For this paper a greater emphasis is laid on the one domain (educational attainment). This domain informed the study appropriately in terms of the desired research question, which was investigated. Also, the design and implementation of the pretest and posttest were aptly carried out. The pretest and posttest items addressed concepts in numeracy, exponents, surds, algebraic expressions, algebraic fractions, linear and quadratic equations, functions and trigonometry. The data arising from the students' written responses were collected and analyzed. This data analysis and discussion were redirected to the theoretical analysis so as to motivate the conclusions made by the researchers. A theoretical analysis employing the domains of sustainable e-learning informs the design and implementation of instruction. The instructional tools for this paper were the use of post-tests and pre-tests. This aspect of the framework then informs the collection and analysis of data. In this paper the statistics from the student responses provided the data. There is a bi-directional interaction between the theoretical analysis and the collection and analysis of data.

Conceptual Framework

This paper lays special emphasis on the domain of *educational attainment*. This is one domain guided by the *domains of sustainable e-learning*. Stepanyan et al. (2013) formulated a coherent body of knowledge on sustainable e-learning. In that paper they emphasize that the lasting success of e-learning endeavors is a growing concern for educational institutions that rely on governmental funding. In this study the researchers considered the domains presented by Stepanyan et al. (2013). For the domain *resource management* the researchers are involved in writing a separate paper to primarily focus on the electronic media used in the Pathfinder project. The researchers have addressed the domain *professional development and innovations* in Ally et al. (2015). For that paper, the researchers referred to the findings of previous South African studies (Brijlall 2011, 2014; Brijlall and Isaac 2011; Brijlall and Maharaj 2009, 2014; Brijlall and Ndlovu 2013; Brijlall et al. 2011, 2012).

METHODOLOGY

This paper utilized a quantitative paradigm. The researchers have used a pretest and a posttest to gauge whether there was a significant difference in the mathematics performance of a group of engineering students. In a quantitative study the focus will be on control of all components in the actions and representations of the participants and the variables (Cohen et al. 2011; Henning 2004; Maree 2007). In this case e-learning was kept constant. A total of 43 participants were selected from two engineering groups of students. The actual variables to be compared were the mathematics concepts tested and they were kept the same in both tests.

The aim of the paper was to determine the effectiveness of e-learning practices used in this study on remediating basic mathematical gaps in prior learning, which have been identified in the at-risk students. With this aim in mind, the researchers sort to foster a rationale for the use of e-learning as a sustainable communication tool in the mathematics learning process. This aim led the researchers to formulate the critical research question: *What can a quasi-experiment reveal about the use of e-learning support materials serving to sustain the academic performance of at risk first year engineering students?*

A purposefully selected sample of first year engineering students was chosen for this project. For this paper, the researchers focus on the pretest (Noor et al. 2014). It is hoped that the pretest would indicate the areas of weaknesses the students have in relation to the high school mathematics syllabus (Department of Basic Education (DoBE) 2011). Once these mathematical weaknesses are identified, other e-learning support materials would be designed to foster e-learning over a sustained time frame. A special pre-test (see Appendix) on basic mathematical competencies, which were prior learning requirements for Math 101, was carried out on mechanical and industrial entry level Math 101 students early in the semester. Students who achieved a mark of less than fifty percent were identified as 'at risk'. Students repeating Mathematics S1 were also included in the 'at risk' group.

RESULTS AND DISCUSSION

Thirty-five questions from the following sections formed the pre-and post-tests: numeracy, exponents, surds, algebraic expressions, algebraic fractions, linear and quadratic equations, functions and trigonometry. The duration of both tests was 1.5 hours. Students were not allowed to use calculators. The total number of students who wrote the post-test on 21st October 2014 comprised 22 mechanical engineering students and 21 industrial engineering students. These students were all registered for a first course in mathematics, namely, Math 101. Questions were also graded into cognitive levels. These are shown in Table 1.

Table 1 shows the questions coded per section and categorized according to four levels described in DoBE (2011: 53). These levels include L1 (knowledge), L2 (routine procedures), L3 (complex procedures) and L4 (problem solving). The researchers all coded the levels separately and later a collective discussion ensued to reach consensus on these levels.

Table 1: Cognitive levels of pre-and post- tests

Question number	*Section*	*Sub-section*	*Cognitive level(L)*
1	Numeracy		1
2	Numeracy		1
3	Exponents and Surds		2
4	Ratio		4
5	Exponents and Surds		3
6	Algebra	Expressions	1
7	Algebra	Expressions	1
8	Algebra	Expressions	2
9	Algebra	Expressions	2
10	Algebra	Expressions	2
11	Algebra	Expressions	2
12	Algebra	Fractions	2
13	Algebra	Fractions	3
14	Algebra	Fractions	2
15	Algebra	Fractions	1
16	Algebra	Equations	2
17	Algebra	Equations	2
18	Algebra	Equations	3
19	Algebra	Equations	2
20	Algebra	Inequalities	2
21	Functions	Function values	2
22	Functions	Function values	2
23	Functions	Line	2
24	Functions	Line	1
25	Functions	Parabola	1
26	Functions	Parabola	1
27	Functions	Parabola	1
28	Functions	Hyperbola	1
29	Trigonometry	Special Angles	3
30	Trigonometry	Identities	2

Eleven of the questions were at level 1, eighteen at level 2 and five at level 3. Questions in the post-test were kept similar to that of the pre-test differing only in the numerical value used. Thus, for example, question 6 for the pre-test read, 'simplify $3a^3\,(2ab^2)$. ', whilst the post-test question 6 read 'simplify $4a^2\,(5a^2b^3)^2$. Both tests were conducted under typical exam conditions and question papers were collected from students on completion of the tests.

Table 2 shows the comparison of the overall results for the 43 candidates who wrote both tests.

Table 2: Comparison of overall report on pre- and post-tests

	Pre-test	*Post-test*
Negative marking used	N	N
Number of test papers processed	43	43
No of questions in the test	35	35
Total number of marks	35	35
Number of candidates scoring 40% or higher	35	40
Number of candidates scoring 50% or higher	12	34
Mean percentage	45	59.65
Mean	15.75	20.44

Of the 43 candidates who wrote both the pre- and post-tests, eight scored less than forty percent in the pre-test while only three scored below forty percent in the post-test. Five more students scored more than forty percent in the post-test than what was recorded in the pre-test. The increase in the number of students scoring more than fifty percent was significant. 34 achieved more than fifty percent in the post-test while only 12 achieved more than fifty percent in the pre-test. Further evidence of improvement in basic mathematics becomes clearer when considering the mean: forty-five percent in the pre-test versus 59.65 percent in the post-test. The improvement must however, be tempered with the standards expected by the researchers. As much as eighty-two percent of the questions were placed on levels 1 and 2, which require basic recall of mathematics concepts or the performing of routine mathematical procedures.

Figure 1 shows a graphical representation (5 number summary) of the comparison between the overall pre- and post-test results.

All critical values comprising the box and whisker diagram show increases. The median value increased from forty-six percent to sixty-three percent whilst the maximum value showed an impressive gain of twenty-nine percent improving from fifty-seven percent to eighty-six percent. Although the minimum value increase

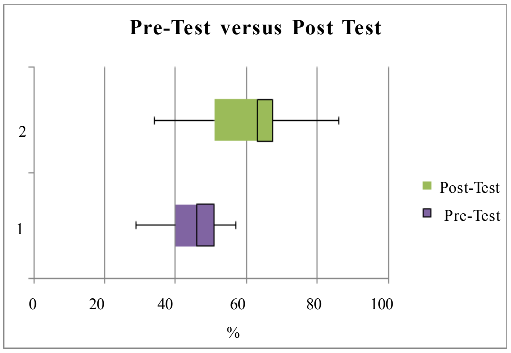


Fig. 1. 5 number summary diagram

was benign it also improved by five percent. The 3rd quartile value of the pre-tests, that is, 51 is the 1st quartile value of the post-test. The 3rd quartile value of the post-test increased from 51 to 67.5. The overall performance shows a general improvement of the group. This improvement suggests the need for a sustained intervention and concurs with Ally et al. (2015).

Individual results become the focus for the remainder of the discussion. Table 3 shows the students' individual performance in the pre- and post-tests. The ranking was obtained directly from the results of the pre-test by arranging them from lowest to highest. A score of less than fifty percent in the pre-test was deemed to be of concern. Such students were identified as at risk and were either inducted into a pathfinder project using e-learning as the primary mode of delivery for academic support in Basic Mathematics or directed to an open e-learning site for all first year mathematics students. Of the 43 students in the group, 31 scored less than fifty percent in the pre-test.

Only three candidates scored less in the post-test than in the pre-test. The biggest decline was the candidate ranked 21st who showed a decrease of twelve percent. The remainder showed improvement with the biggest gain from the student ranked 19th. This student doubled the performance obtaining eighty-six percent in the post-test from a low of forty-three percent in the pre-test. 15 candidates increased their performance by more than twenty percent whilst 29 showed improvements of more than ten percent. On average, performances improved by fourteen percent. Further investigation is needed to address individual performances. However, this does not fall within the ambit of this paper.

Table 3: Students' comparative performance in pre-and post-tests

Ranking	*Pre %*	*Post %*	*% in/ decrease*
1	29	46	17
2	31	54	23
3	31	63	32
4	34	69	35
5	34	54	20
6	37	51	14
7	37	51	14
8	37	66	29
9	40	71	31
10	40	63	23
11	40	46	6
12	40	43	3
13	43	63	20
14	43	86	43
15	43	40	-3
16	43	37	-6
17	43	49	6
18	43	51	8
19	43	51	8
20	46	63	17
21	46	34	-12
22	46	57	11
23	46	63	17
24	49	51	2
25	49	69	20
26	49	51	2
27	49	66	17
28	49	54	5
29	49	71	22
30	49	60	11
31	49	49	0
32	51	54	3
33	51	63	12
34	51	77	26
35	51	77	26
36	51	77	26
37	51	66	15
38	51	66	15
39	54	74	20
40	54	63	9
41	54	66	12
42	57	69	12
43	57	71	14

CONCLUSION

The thirty-five multiple-choice questions in the pre- and post-tests covered basic skills required in numeracy, exponents, surds, algebraic expressions, algebraic fractions, linear and quadratic equations, functions and trigonometry. The performances of students in the pre- and post-tests was discussed and analyzed as a group as well as individuals to ascertain whether the mathematics gap in first year engineering students could be addressed by using e-learning support materials. The improved positive performances indicate that the one domain within the three domains of sustainable e-learning, namely, educational attainment, could be met by using suitable e-learning methods. Aligning the pre-and post- tests along similar basic mathematics as well as cognitive levels was necessary to ascertain whether candidates showed improvement in the understanding of basic mathematics concepts. This was aptly shown in the analysis considering the data first as a collective and then as individuals.

RECOMMENDATIONS

The design of appropriate e-learning content to ensure learning objectives are met and the need to define and monitor every activity is paramount in addressing the mathematics gap of first year engineering students. Systematic management of the process of e-learning is a major contributing factor of its success leading to sustainable learning. It is further recommended that all first year engineering students enrolled for Mathematics 101 attempt the pre-test as a process of early identification of at risk students.

ACKNOWLEDGEMENTS

The researchers in this study thank the Durban University of Technology's E-Learning Committee and Department of Mathematics for funding this research.

REFERENCES

Ally A, Brijlall D, Rajah SS, Day D, Maharaj A, Lortan D 2015. Using e-learning support as a sustainable communication tool. *Journal of Communication*, 6(1): 172-181.

Asiala M, Brown A, DeVries D, Dubinsky E, Mathews D, Thomas K 1997. A framework for research and curriculum development in undergraduate mathematics education. *Research in Collegiate Mathematics Education,* 6: 1-21.

Bansilal S, Brijlall D, Mkhwanazi T 2014. An exploration of the common content knowledge of high mathematics teachers. *Perspectives in Education,* 32(1): 34-50.

Brijlall D 2011. A case study of lecturers' views on content knowledge and practice. In: T Mamiala, F Kwayasi (Eds.): *Proceedings of the Nineteenth Annual Meeting of the Southern African Association for Research in Mathematics, Science and Technology Education,* North-West University, 12-15 January 2011, Mafekeng, South Africa, pp. 34 – 50.

Brijlall D 2014. Exploring the pedagogical content knowledge for teaching probability in middle school: A South African case study. *International Journal of Educational Sciences*, 7(3): 719-726.

Brijlall D, Bansilal S, Moore-Russo D 2012. Exploring teachers' conceptions of representations in mathematics through the lens of positive deliberative interaction. *Pythagoras*, 33(2): Art #165, 8 pages.

Brijlall D, Isaac V 2011. Links between content knowledge and practice in a mathematics teacher education course: A case study. *South African Journal of Higher Education*, 25(4): 680-699.

Brijlall D, Maharaj A 2009. Using an inductive approach for definition making: Monotonicity and boundedness of sequences. *Pythagoras,* 70: 68-79.

Brijlall D, Maharaj A 2014. Exploring support strategies for high school mathematics teachers from underachieving schools. *International Journal of Educational Sciences*, 7(1): 99-107.

Brijlall D, Maharaj A 2015. Exploring pre-service teachers' mental constructions when solving problems involving infinite sets. *International Journal of Educational Sciences*, 9(3): 283-296.

Brijlall D, Ndlovu Z 2013. Exploring high school learners' mental construction during the solving of optimization. *South African Journal of Education,* 33(2): Art #679, 18 pages.

Brijlall D, Maharaj A, Bansilal S, Mkhwanazi T, Dubinsky E 2011. A pilot study exploring pre-service teachers understanding of the relationship between 0, 9 and 1. In: H Venkat, AA Essien (Eds.): *Proceedings of the 17th Annual AMESA National Congress,* 10-15 June 2011, Witwatersrand, South Africa.

Cohen L, Manion L, Morrison K 2011. *Research Methods in Education.* 7th Edition. London: Routledge.

DoBE (Department of Basic Education) 2011. *Curriculum and Assessment Policy Statement (CAPS). Mathematics Grades 10-12.* Pretoria, South Africa: DoBE.

Henning E 2004. *Finding Your Way in Qualitative Research.* Pretoria: Van Schaik

Maree K 2007. *First Steps in Research.* Pretoria: Van Schaik.

Ndlovu Z, Brijlall D 2015. Pre-service teachers' mental constructions of concepts in matrix algebra. *African Journal of Research in Mathematics, Science and Technology Education*, DOI: 10.1080/10288-457.2015.1028717.

Stepanyan K, Littlejohn A, Margaryan A 2013. Sustainable e-learning: Toward a coherent body of knowledge. *Educational Technology and Society*, 16(2): 91-102.

Paper received for publication on February 2015
Paper accepted for publication on November 2016

APPENDIX

For the pretest the reader is referred to the paper by Noor et al. (2014). The researchers present here the posttest.

Post-Test

Complete the following information:

Surname	
First Names	
Student Number	
Signature	
Programme of Study	

INSTRUCTIONS

1. All questions are multiple- choice and have a number of possible answers labeled A, B, C, or D. Select only one option.
2. Record your answers to the multiple-choice questions on the **Multiple choice Response Card** Read the instructions – use a black/blue pen or pencil only. Shade in your student number and complete the information at the back of the card.
3. The whole booklet as well as the **Multiple Choice Response Card** must be handed in.
4. You may write on the test booklet if you need to do rough work.
5. Calculators are **NOT ALLOWED** in this test.

1. Which value is the smallest?
A. 8.35 B. 0.835 C. 83.5 D. $8\frac{35}{100}$

2. Which number is the odd one out?
A. 0.45 B. $\frac{45}{100}$ C. $\frac{9}{20}$ D. 4,5

3. Find the value of $2\sqrt{25}-\sqrt[3]{27}+3\sqrt[4]{16}$.
A. 7 B. 13 C. 14 D. 12

4. A rugby player scores 85% of his team's 40 points. How many points were scored by the rest of his teammates?
A. 85 B. 32 C. 6 D. 34

5. Evaluate: $\left(\frac{2}{2^{-1}-3^{-1}}\right)^2$
A. 144 B. 12 C. 4 D. 9

6. Simplify: $4a^2(5a^2b^3)^2$
A. $40a^8b^6$ B. $100a^6b^5$ C. $100a^6b^6$ D. $40a^6b^5$

7. $(2x+1)^2$ can also be written as…
A. $4x^2+4x+1$ B. $4x^2+1$C. $4(x+1)^2$ D. $4x^2+2x+1$

8. The highest power of *x* in the expression $[5(x^4+5)(x^2-1)]^3$ is
A. 20 B. 24 C. 9 D. 18

9. A possible simplification of $\sqrt{x^2-6x+9}$ is:
A. $-x-3$ B. $x-\sqrt{6x}+3$ C. $x-3$ D. $x+3$

10. Expand and simplify. $\left(x+\frac{2}{x}\right)\left(x-\frac{2}{x}\right)$
A. $x^2+\frac{4}{x^2}$ B. $x^2-\frac{4}{x^2}$ C. $x^2+4x+\frac{4}{x^2}$ D. x^2

11. Which of the following is a factor of both x^2+2x-8 and x^2-5x+6
A. x-3 B. x+3 C. x-2 D. x+2

12. $\frac{a}{b}-\frac{b}{a}=$
A. $\frac{a^2-b^2}{ab}$ B. 0 C. $\frac{a-b}{ab}$ D. a^2-b^2

13. Simplify: $\frac{a^2-b^2}{\frac{1}{a}+\frac{1}{b}}$
A. $a-b$ B. a^3-b^3 C. $a+b$ D. $ab(a-b)$

14. Simplify: $\frac{x^2-2x+1}{x^3-2x^2+x}$

A. x^3+1 B. x^3 C. $\frac{1}{x}$ D. x

15. Which answer is applicable to the following expression? $\frac{b+c}{a}$

A. Cannot be simplified B. $\frac{b}{a}+\frac{c}{a}$ C. $b+c\ \div a$ D. $\frac{a}{b}+\frac{a}{c}$

16. Solve for t: $\frac{t}{3}-\frac{4}{7}=\frac{2}{7}$

A. $\frac{18}{7}$ B. $\frac{6}{21}$ C. $\frac{7}{18}$ D. $-\frac{1}{7}$

17. Find one root of the equation: $x^2-5x=6$.

A. x =1 B. x=2 C. x=3 D. x=-1

18. If α and β are the roots of the equation $2x^2+5x-18=0$, what is the value of α + β?

A. $-\frac{7}{2}$ B. $-\frac{5}{2}$ C. $\frac{5}{2}$ D. 0

19. Find y in terms of a and b if $\frac{3ay}{8b}=-5$

A. $-\frac{40b}{3a}$ B. $-\frac{40a}{3b}$ C. $\frac{-15a}{8b}$ D. $-\frac{3a}{40b}$

20. Solve for x: $-5x+8\leq -7$.

A. $x\geq 3$ B. $x\leq 3$ C. $x\leq\frac{1}{5}$ D. $x\geq\frac{7}{13}$

21. If $f(x)=2\sqrt{x^2+25}$ find the value of $f(5)$.

A. 0 B. 20 C. $10\sqrt{5}$ D. $10\sqrt{2}$

22. If $f(x)=x^2-2x+4$. then $f(a+1)=$

A. a^2+7 B. a^2+3 C. a^2-2a+3 D. a^2-2a+4

23. The standard form of the equation $5x+3y=-12$ is:

A. $y=-\frac{3}{5}x+12$ B. $y=\frac{3}{5}x-12$ C. $y=\frac{5}{3}x+4$ D. $y=-\frac{5}{3}x-4$

24. If the line with equation $y=-3x-1$ is perpendicular to the line with equation $y=ax+5$ then the value of a is

A. -3 B. 3 C. $\frac{1}{3}$ D. $-\frac{1}{3}$

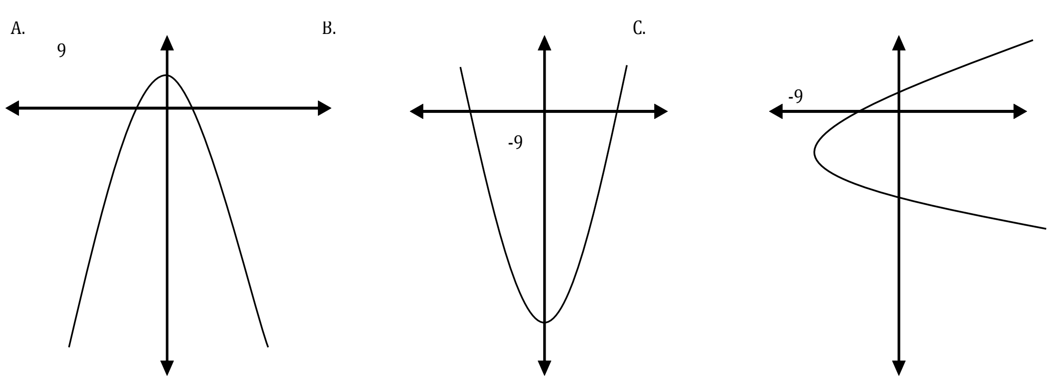
25. The parabola with equation $y=x^2-4$ has

A. Two x-intercepts B. No x-intercepts D. One x-intercept D. No y-intercept

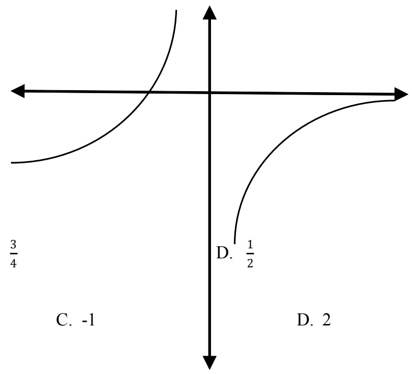
26. The parabola having equation $y=(x-3)^2+5$ has a maximum turning point at

A. $(3;-5)$ B. $(3;5)$ C. $(-5;-3)$ D. $(-3;-5)$

27. Which of the following best represents the function $y=-x^2+9$?



18. Consider the following graph.
Which equation ***best*** describes the graph?
A. $xy = k\ , k > 0$
B. $xy = k,\ k < 0$
C. $y = k^x, k > 0$
D. $y = k^x, k < 0$



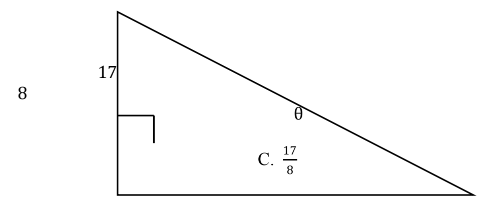
19. If $\theta = 60^o\ find\ the\ value\ \ sin\frac{\theta}{2} + \frac{cos\theta}{2}$.
A. $\frac{1}{4}$ B. $-\frac{1}{4}$ C. $\frac{3}{4}$ D. $\frac{1}{2}$

20. Find the value of $1 - sin^2\theta - cos^2\theta$.
A. 0 B. 1 C. -1 D. 2

21. A possible simplification of $\frac{\sqrt{1-cos^2x}}{sinx}$ is :
A. 1 B. 0.5 C. 0 D. 2

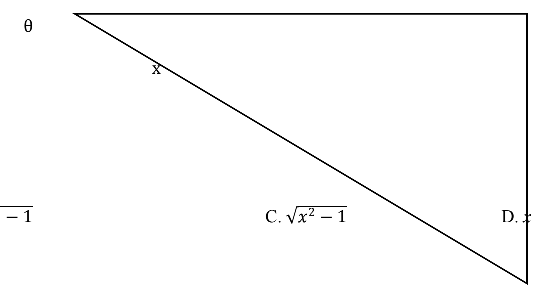
22. Calculate the value of $\sin(2x - 30^0)$ correct to two decimal places if $cosx = \frac{1}{2}\ and\ x\epsilon[0^0; 90^0]$.
A. 0 B. $\frac{1}{2}$ C. $\frac{\sqrt{3}}{2}$ D. 1

23. Using the information in the figure, what is the value of $sin\theta$?



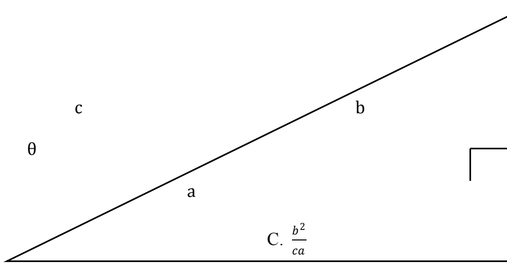
A. $\frac{8}{17}$ B. $\frac{15}{17}$ C. $\frac{17}{8}$ D. $\frac{15}{8}$

24. In the right-angled triangle shown, what is $tan\theta$?



A. x B. $x\sqrt{x^2-1}$ C. $\sqrt{x^2-1}$ D. $x - 1$

25. Use the information in the figure to find $sin\theta.tan\theta$.



A. $\frac{a^2}{cb}$ B. $\frac{b}{c}$ C. $\frac{b^2}{ca}$ D. $\frac{ac}{b^2}$