Effect of expressive writing on math anxiety of engineering students

Vikrant Jaltare¹, Kshipra Moghe¹
¹ College of Engineering, Pune, India
² College of Engineering, Pune, India
E-mail: jaltarevr16.elec@coep.ac.in
E-mail: kam.appsci@coep.ac.in

Abstract. Math Anxiety is the negative reaction to situations involving mathematical computation. Studies have shown that math anxiety restricts access to working memory, which is essential to solve mathematical problems. Using the math anxiety—performance relationship, the effectiveness of expressive writing as a remedial measure was tested. Participants (N=42) were asked to either sit quietly (control group) or were told to write about their thoughts and feelings (experimental group) prior to taking a math test. The experimental group participants performed significantly better than the control group participants. A significant improvement in performance due to expressive writing shows a positive reaction towards math anxiety.

1. Introduction
Math anxiety is defined as tension, apprehension and fear of situations involving mathematics [1] and is associated with poor math performance. Individuals with a high math anxiety receive lower grades in math from elementary school (especially primary schools in India) through college as compared to their lower math anxiety counterparts [2]. Furthermore, individuals with high math anxiety tend to avoid courses and careers involving mathematics [3]. As many as 25% 4-year university students and 80% community college students suffer from high math anxiety in the US [4].

Math anxiety is known to cause an everlasting effect on any assessment that is related to the subject. The past studies have effectively analysed the deleterious effects of math anxiety on school going students and university students in the US. However, it was hard to find a study that supports this with respect to the Indian students. The students of engineering from Indian institutions are found to perform significantly worse in math as compared to other subjects. Engineering students already have an edge in their functional working memory given their training in structured thinking; it is required to do tasks like numerical computation and comparison. This skill is automatically assessed through the various Engineering entrance exams like the Joint Entrance Examination (JEE) and Common Entrance Test (MH-CET) which are mandatory to qualify to study an Engineering program in India. Further, advanced math requires an insightful understanding of the subject and mastery in application of basics. Although research suggests that math anxiety deteriorates performance in math tests, it cannot always be considered as a proxy for the poor math skill. Hence, anxiety alone cannot be attributed to poor performance of engineering students in math. However, working memory,
which is a cognitive ability to hold and manipulate task related information is shown to be seriously hampered by math anxiety [5]. This is particularly observed amongst the Direct Second Year \(^1\) (henceforth, DSY) students in the Indian engineering institutes. Hence, a wide gap between the performance in math and other core subjects of the respective disciplines is observed in the DSY students. These observations were the underlying motivation in studying whether anxiety plays a significant role in the poor math performance of students, especially DSY students.

Expressive writing is a simple clinical technique that encourages individuals to write freely about their thoughts and feelings about an important stressor they are facing [6]. Previous studies indicate that several bouts of 15-20-minute-long expressive writing provide physical and psychological benefits for both clinical patients (e.g. depression patients) as well as non-clinical patients (e.g. first year college students). Expressive writing has shown to be significantly successful in increasing the availability of working memory resources [7], in mitigating the effects of stress on examination performance [8]. Also, it has been found that writing about negative feelings and thoughts prior to taking a high-stake test, significantly improves performance of students in the respective tests [9, 10].

Based on the studies conducted earlier, we decided to explore whether expressive writing could alleviate negative effects of anxiety on math performance. It is, however, seemingly unrealistic to claim that a single bout of expressive writing could tackle the powerful, long held worries about math in a student’s academic development. Furthermore, only writing about thoughts and feeling may not be able to offset the socio-personal psychological factors like lower self-efficacy, self-doubt, and lack of enthusiasm and interest in math [11]. On the other hand, if math worries are in fact a major contributing factor in the poor performance of DSY students, then a single bout of expressive writing is expected to show significant changes in performance linked to high working memory requirements and the application-type questions which requires the students to apply the theoretical knowledge to solve a real-life problem.

The experimental design in this study was based on the procedure conducted by Park, Beilock and Ramirez [12], as described in their paper titled ‘Role of Expressive Writing in Math Anxiety’. The experiment was conducted on students of the Midwestern University. The invited participants were pre-screened for their anxiety levels prior to the test using SMARS test and then divided in two groups of almost equal number of people with same anxiety levels. One of the groups received expressive writing session and the other one (control group) were given the test without it. The instructions were carefully read out to the students prior to the expressive writing session. Their final performance was evaluated based on error rates weighted with the type of question, i.e. whether it involved critical thinking or not. Hence, the goal of the experiment was not only to find whether math performance improved after expressive writing, but also to assess its application in managing students’ overall academic performance and in addressing anxiety related issues with novelty.

2. Methods

2.1. Sample

A random group of DSY students taking the same course in Multivariate Calculus, who had been taking the said course for the past 3\(\frac{1}{2}\) months comprised of the sample. There were 42 participants in total; \(N = 42\), \(M_{age} = 19.5\) years, age range 19-20 years. The experimental group consisted of \(N_e = 27\) participants and control group consisted \(N_c = 15\) participants.

\(^1\) DSY students are those who start the engineering program after their diploma course and directly enter second year of engineering. It has been long observed that these students perform at par with other non-diploma students in all subject except math, which in turn is an indication of the possible occurrence of anxiety in any math exam. Thus, choosing the DSY students, served as a control mechanism as it ensured that the participants had relevant technical skills but poor skills in math.
Participants were divided into the experimental and control groups randomly and not based on previous scores or disciplines.

2.2. Materials
The experiment consisted of an objective-type questions test. The test was simulated like an objective-type examination in engineering course. All the questions were math based and in sync with the concepts which were covered in the course till that point of time, with due permission and guidance of the course faculty. The questions were both ‘Multiple Choice’ and ‘Fill in the Blank’ type. These questions were broadly categorized into 3 types: Computational Ability (CA), Application (AP) and Critical Thinking (CT) Questions. The CA questions required application of only one formula but involved computing and simplifying algebraic expressions and numerical calculations. Here, the emphasis was not on numerical calculations since like in any other engineering test, the participants were permitted to use calculators. However, the algebraic manipulations required to solve these questions were demanding, for example, find parametric equation of helix given some parameters. Since algebraic manipulation requires storing a temporary bit of information at every step and solving for the next at the same time, these questions require a student’s access to working memory and are relevant to the study. The AP questions required the participants to apply two or more formulae and interpret the result before arriving at the required solution. These questions involved active use of working memory and cognitive abilities and hence were given more credit in terms of marks for correct responses at the time of evaluation. The CT questions required the participants to read a small passage relating to an application of more than two concepts. These questions tested if the participants could quickly understand the matter and apply the previously learnt concepts. These questions were computationally easy – no long calculations or simplification was required to answer them – but focused more on the insightful application of concepts. These questions had the maximum weightage in terms of marks if answered correct. All the questions were in English and had the same set of symbols which the students were familiar dealing with from their course.

2.3. Procedure
The process began with a set of instructions given to the experimental group, which were read aloud, and the participants were asked to read along silently with the narrator. This was done to ensure that every student went through the entirety of instructions and understood them well. The detailed instructions are presented in the Appendix. Participants in the experimental group were given 7 minutes [13] to write their feelings and emotions. After this round of expressive writing, the participants could start answering their test. The participants in control group were asked to sit quietly, without introducing any instructions, till the question papers were distributed. Hence it was a regular test situation for them or ‘business as usual’. They immediately started solving the questions after distribution of the papers. A time limit of 30 minutes was given to solve 10 questions to both the groups. All the question - types, CA, AP and CT, had 4 options each. There were 4 questions from each of the CA and AP sections and 2 questions from the CT section. At the end, the question papers and the responses were collected.

2.4. Scoring
The primary data was the responses to the questions submitted by the participants. The expressive writing responses served as secondary data. The responses from both the groups were analyzed using the same marking scheme. 1 point was given to every correct CA question and zero points were given for incorrect responses. For AP type questions, 2 points were given for every correct response, zero points were given for incorrect responses. However, for these questions, two closely related options were given for each question, one of which was right.
Considering the strict time limits and computational effort coupled with the need to apply concepts in these questions, if the student selected the either of the two closely related options, 1 point was given. For CT Questions, 4 points were given for fully correct response. These questions required students to select one or more correct responses. In case of partially correct response, 1.5 points were given to the student. In case of wrong response, zero points were given. For question – type - wise analysis, the scores from individual sections (CA, AP and CT) were considered separately. For analysis of total scores, the grand total score was considered. The analysis was done using MATLAB and t-test was performed as the test of statistical significance. The distributions of scores were found on question – type – wise basis and total score.

3. Results

The analysis was done on two parameters: 1. distributions of performance of students in each group, question – type – wise, and 2. distributions of scores of overall performances of both the groups.

3.1. Question-type-wise Analysis

A non-significant change in the Computational Ability (CA) type questions was anticipated. Since, these questions were designed to test the skills required to manipulate simplistic data, engineering students are trained enough to tackle these questions even when under stress. It was observed that experimental group (M = 54.6% \( \sigma = 0.962 \)) did not perform significantly better than control group (M = 50.01%, \( \sigma = 1 \)) with p > 0.1, thereby reflecting the initial expectation. Although, experimental group performed a bit better than control group participants on CA type questions, their performance was not statistically significantly better than control group students as indicated by p > 0.10. The Application (AP) type questions were the primary focus of the analysis, since, these questions demanded application of concepts and stress is a derogatory factor in optimal use of working memory, cognitive abilities and mathematical skills. The control group (M = 36.92%, \( \sigma = 1.3558 \)) performed significantly worse than the experimental group students (M = 45.21%, \( \sigma = 0.84732 \)), p < 0.07. This was a clear indicator that math anxiety did play a role in hampering the application of mathematical skills in stressful situations as indicated by the significantly poor performance of control group students. Finally, analysis of Critical Thinking (CT) questions was conducted. From the experimental design purview, these questions generated some reservations since these questions required a lot of effort to solve and were tricky to get right. Hence, there was a possibility that the participants may not solve these questions at all. However, the experimental results refuted this notion. During the analysis it was revealed that almost 52% students in experimental group attempted the CT questions, however, only 40% students in the control group tried attempting the CT questions. Furthermore, the control group students (M = 8.25%, \( \sigma = 0.4879 \)) again performed significantly worse than their experimental group counterparts (M = 26.13%, \( \sigma = 0.57981 \)) with p < 0.05.

3.2. Analysis of Total Scores

The results of overall performance distribution are the ones that concerned the study the most, because ultimately, the final score is the one that a student gets and is counted for grading which then determines the general level of mastery of the subject. The study showed that the control group (M = 45.7%, \( \sigma = 3.3566 \)) again performed significantly worse than experimental group (M=51.2%, \( \sigma = 2.4149 \)) with p < 0.09. This distribution also showed that the experimental group had a much smaller standard deviation than the control group. While this effect may be because there were a smaller number of students in control group than the experimental one, their standard deviations are significantly different p < 0.05. This indicates, that the experimental group not only performed well, but also that there were more participants who got marks closer to the mean value of the group than those who scored much lesser than the mean value.
Figure 1. Question – Type - wise distribution of performance of experimental and control groups- demonstrates, in a comparative way, the performance of students for each of the question type i.e. CA, AP, CT questions. The distribution represents number of students against the fraction of questions solved correctly, expressed as percentage.

value as compared to the control group. Hence, it can be inferred that overall the experimental group performed better than the control group.

3.3. Expressive Writing Analysis
While collecting the responses, the confidentiality of participants was given paramount importance, and the response sheets did not make writing names mandatory. However, based on the written matter, it was qualitatively observed that out of 27 participants in the group, only 7 participants wrote positively about math test and math as a subject in general. These participants showed enthusiasm towards math by citing that they were always ready for solving math or that they saw math as a scoring subject. However, out of the remaining 20 participants, 12 participants wrote negatively about math and exams in general. Many of the participants then responded that they get nervous and panicked during tests, especially during math related tasks and that they have a childhood fear of math. The remaining 8 responses were neither entirely negative nor positive, who wrote that they liked math as a course but when it came to solving tricky questions in the examination, they lose confidence and then the frustration takes a toll on their ability to apply the ideas which they were initially confident about and hence, fail to reproduce it in the tests. These students also wrote that such a cumulative effect of not being able to answer correctly despite knowing the correct approach has made them more averse towards math, overall. It is, hence, evident that 70% students taking the test were anxious about math test either inherently or due to prolonged poor performance which hampered their liking toward the subject.

The responses of participants included phrases like; looking forward to taking the test, enjoy solving challenging math problems, solving problems makes them happy etc
Figure 2. Distribution of the overall performance of control group and experimental group gives a comparison of performance of students in the test. The distribution represents number of students against the fraction of score obtained in the test expressed as percentage. The score was calculated as a weighted sum as indicated in the marking scheme.

Figure 3. Analysis of expressive writing responses. The responses were categorized into three groups - Positive, Negative and Neither Positive nor Negative – based on the kind of words used in the written response. The percentage of students giving a response was considered for each of the three responses and corresponding bar diagram was compiled.
4. Discussion and Conclusion

The performance of students did not show significant improvement for the questions involving only algebraic manipulations and use of only one mathematical formula, i.e. CA type questions. However, there was a significant improvement in performance of the experimental group, in the questions involving application of several ideas or mathematical formulae to solve a problem i.e. AP and CT question types. The results of AP type and CT type questions, thus, gave significant support to the hypothesis that expressive writing does alleviate the derogatory effects of anxiety on performance in stressful situations like taking a math test. These results indicate that two groups which were drawn from a population having similar attributes in terms of mathematical skills, showed different levels of performance after a single bout of expressive writing.

The overall performance of participants was also found better among the experimental group than the control group. Further, results also indicate that the variation in performance of experimental group was much smaller than that of control group. This shows that the experimental group indeed had better access to working memory and could use their mathematical and cognitive skills better than their control group counterparts. More than half (70%) students responded either completely negatively about math or expressed their dislike toward the subject due to a streak of bad performances in previous tests. This high number of students anxious about math is an alarming state because math forms the foundations of engineering program and is the most essential tool which an engineer must have. If anxiety is a strongly contributing issue which keeps many to not perform well in math, then it is something to be tackled with a serious thought. The study does indicate that expressive writing could be one efficient, fast and easy way to address this problem as it does show significant performance changes in the participants who were exposed to it. Hence, these results may be considered as an impetus to inculcation of expressive writing as a remedial strategy for low performing students.

Other than finding whether expressive writing could help boost performance of all students in general, there is a possibility that this exercise affected the students who were never anxious. It is possible that making less anxious students to write about their feelings and thoughts could have induced nervousness which was never present [13]. However, this study did not find enough evidence \( p > 0.10 \) to support this notion, and hence, it can be said that expressive writing helped anxious students, without compromising the performance of students with low anxiety.

The expressive writing reduces the possibility that math related worries and apprehension would capture the attention in the test [14]. Writing about performance issues may enhance access to the working memory resources and help the students better understand the emotional experience [15] which leads to adoption and execution of more effective emotion regulation strategies [16]. However, when it comes to emotional expression, people from collectivist societies, like India, are weakly correlated with higher expression norms as opposed to individualistic societies, like USA [17]. This is important since the base of this study was expressive writing and this fundamental requirement could have been hampered by the very nature of participants, which is beyond their personal control as it is culturally shaped.

Nevertheless, this study does indicate that even in collectivist societies, when introduced at the right time and for the right purpose, expression can indeed be beneficial and successful. Since, expressive writing helps an individual to distance themselves from their immediate sources of stress, which is an important component in effectiveness of expressive writing the purpose of this study was well accomplished.

The results presented in this study should motivate educators, policymakers, parents, guardians and counsellors to consider expressive writing to respond effectively to high anxiety students. The work reported here demonstrates effectiveness of expressive writing and if a single bout of expressive writing can help students significantly in their performance, it is safe to conclude that a series of bouts might help them overcome their math anxiety. Not just that, this strategy may also be incorporated as a regular practice to help students tackle other anxiety
related issues.

Acknowledgments
The authors would like to acknowledge the assistance from the Department of Applied Science throughout the length of the research. The authors also appreciate the assistance from the colleagues at the College of Engineering, Pune. Finally, the authors are grateful for the valuable inputs from the Department of Mathematics, College of Engineering, Pune.

Appendix
The instructions given to the students prior to the test.
Please take the next 7 minutes to write as openly as possible about what you think and how you feel regarding the math problems you are about to perform. In your writing, I want you to really freely explore your thoughts and feelings as you are getting ready to start this math test. You might relate your current thoughts and feelings to the way you have felt during other similar situations at school or in other situations in your life. Please try to be as open as possible as you write your responses; there are no definite right and wrong responses, what you write is correct for yourself. Remember, what you write is not related to your personal identity, so there is absolute confidentiality. A small list comprising of examples about common feelings and thoughts is given below for your reference. You may add more words/phrases describing your feelings and thoughts as per your need.

The participants were to respond as per the instructions to a given set of statements; a sample is shown below:

- I’m feeling nervous right now.
- I panic easily during a math test.
- For me Math is an intimidating/scary subject.

References
[1] Ashcraft M H and Moore M A 2009 Journal of Psychoeducational Assessment 27 197–205
[2] Betz N E 1978 Journal of Counseling Psychology 25 441–448
[3] Hembree R 1990 Journal for Research in Mathematics Education 21 33–46
[4] Yeager D S 2012 productive persistence: A practical theory of community college student success. Paper presented at the 2012 annual meeting for the American Educational Research Association
[5] Engle R W 2002 Current Directions in Psychological Science 11 19–23
[6] Pannebaker J W and Beall S K 1986 Journal of Abnormal Psychology 95 274–281
[7] Klein K and Boals A 2001 Journal of Experimental Psychology 130 A 520–533
[8] Faust M W, Ashcraft M H and Fleck D E 1996 Mathematical Cognition 2 25–62
[9] Gortner E M, Rude S S and Pannebaker J W 2006 Behavior Therapy 37 292–303
[10] Kross E and Ayduk O 2011 Current Directions in Psychological Science 20 187–191
[11] Ramirez G and Beilock S L 2011 Science 331 211–213
[12] Wood E 1998 Math anxiety and elementary teachers: What does research tell us? for the learning of mathematics (Preprint http://ble/40248135)
[13] Park D, Beilock S L and Ramirez G 2014 Journal of Experimental Psychology 20 103–111
[14] Lepore S J, Greenberg M A, Bruno M and Smyth J M 2002 The writing cure: How expressive writing promotes health and emotional well-being ed Lepore S J and Smyth J M (Washington, DC: American Psychological Association) pp 99–117
[15] Gohm C L and Clore G L 2000 Personality and Social Psychology Bulletin 26 679–697
[16] Schmeichel B J and Demaree H A 2010 Emotion 10 739–744
[17] Matsumoto D et al. 2008 Journal of Cross-Cultural Psychology 39 55–73