ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022

Paper ID #36722

Fast-Forward Program: PSVT:R Test Results and Analysis

Lauren Fogg

Lauren Fogg is a 2nd-year Ph.D. student in Engineering Education at Louisiana Tech University. She has a Bachelor's degree in Mechanical Engineering. Her research interests are diversity, gender equity, retention, project-based learning, and cognitive models of problem-solving. She is also serving as the Project Coordinator for an NSF-funded S-STEM program.

Allissa Taylor Gros

Allissa Gros (she/her) is a second year Computational Analysis and Modeling PhD student at Louisiana Tech University in Ruston, LA. She has a bachelors in Mathematics with a minor in education UTeach. Allissa love puzzles, graph theory, diversity in education, and her wonderful dog, Apollo!

Katie Evans (Dean)

Dr. Katie Evans is Professor of Mathematics and the Dean of Science and Engineering at Houston Baptist University (HBU). Prior to HBU, she was on faculty at Louisiana Tech University for 16 years in the College of Engineering and Science, where she served as Associate Dean of Strategic Initiatives, Academic Director of Mathematics & Statistics and Online Programs, the Entergy LP&L/NOPSI #3 & #4 Professor of Mathematics, the Director of the Integrated STEM Education Research Center, and the Director of the Office for Women in Science and Engineering. Dr. Evans serves as on the Interim Executive Committee and as Chair of the New Programs Committee for the Grand Challenges Scholars Program, founded by the U.S. National Academy of Engineering. She earned her B.S. in Mathematics from Morehead State University, and her M.S. and Ph.D. in Mathematics at Virginia Tech. After a postdoctoral position in Mechanical Engineering at Oregon State University, she joined Louisiana Tech, where she is now Professor Emerita. Dr. Evans' current scholarship focuses on STEM Education.

Marisa Orr

Marisa K. Orr is an Associate Professor in Engineering and Science Education with a joint appointment in the Department of Mechanical Engineering at Clemson University. Her research interests include student persistence and pathways in engineering, gender equity, diversity, and academic policy. Dr. Orr is a recipient of the NSF CAREER Award for her research entitled, ”Empowering Students to be Adaptive Decision-Makers.”

Catherine Belk

I am a doctoral student in the Engineering and Science Education department at Clemson University. I received my B.A. degree in Religion and my B.S. degree in Physics from High Point University in 2012. I received my M.S. degree in Medical Physics from East Carolina University in 2014. I have taught introductory physics lab courses at Clemson University. My primary research focuses embodied cognition, spatial abilities and student gestures.

Ethan Hilton (Assistant Professor)

Dr. Ethan Hilton is an assistant professor of Mechanical Engineering at Louisiana Tech University in Ruston, LA, where he has been since September 2019 after receiving his Ph.D. from the Georgia Institute of Technology. Dr. Hilton's work focuses on Engineering Design and Engineering Education, focusing on design methodology, project-based learning, and

hands-on learning in informal environments. He has also worked on Broadening Participation in STEM through studying barriers in and throughout Engineering curricula for underrepresented groups. He is a member of Louisiana Tech's Integrated STEM Education Research Center (ISERC). He has assisted in developing and implementing numerous course projects throughout the College of Engineering and Science. He is passionate about making engineering design accessible to all by providing hands-on opportunities to connect engineering theory to real design problems and reducing barriers for students from any background to see the need for their perspective in any design problem.

Mitzi Desselles (Associate Professor)

Fast-Forward Program: PSVT:R Test Results and Analysis

Abstract

In this paper, we discuss the spatial visualization curriculum: Developing Spatial Thinking, endorsed by ENGAGE, and the Purdue Spatial Visualization Test: Rotation test results from participants in an NSF S-STEM-funded sophomore bridge program for engineering majors, known as the Engineering Fast-Forward Program. This paper also discusses the impact the spatial visualization curriculum has had on the students in the Fast-Forward program. The Fast-Forward program, which has been offered every summer from 2017 to 2021, is designed for students who have unmet financial needs which are determined by the financial aid office on campus. This program seeks to retain students in engineering programs as well as increase the number of people in the engineering workforce. Participants in the Engineering Fast-Forward Program take Statics and Mechanics of Materials, Calculus III, and Professional Planning with Spatial Visualization in the summer before their sophomore year. These classes normally taken in the Fall of their Sophomore years give the students an opportunity to get a head start in their Sophomore curriculum. Professional Planning with Spatial Visualization is a course where students are taught from the Developing Spatial Thinking curriculum as well as participating in other professional development activities such as resume building, mock interviews, and industry visits.

The participants take the Purdue Spatial Visualization: Rotations (hereafter referred to as the PSVT:R) as a pre and post-assessment in the course. Statistical analysis is completed using the results from these tests including data from all five summers. The statistical analyses included: paired sample t-tests, independent sample t-tests, and repeated measure ANOVA tests. The goal of the analysis was to see if students from traditionally underrepresented groups (URG) had a higher level of improvement on the PSVT:R than students from non-underrepresented groups (non-URG). For the purpose of the statistical analysis of this work requiring similar sample sizes for the two groups, non-URG students are White and Asian males with URG students being the students from the cohorts identifying with any other demographic descriptions. The results of the statistical analysis show a statistical significance from pre to post results for all of the students. URG and non-URG students' scores are increasing from pre- to post-test at the same rate. However, URG students start and end with lower scores than the non-URG students. We conclude that the Developing Spatial Thinking curriculum is improving the spatial visualization skills of all students, yet is unfortunately not closing the gap between the two groups.

1 Introduction and Background

The Fast-Forward Engineering Program is a scholarship program at Louisiana Tech University funded by the National Science Foundation that allows rising sophomore engineering students to continue their curriculum ahead of schedule [1]. Eligibility is based on unmet financial need and on-track degree progression to achieve a 4-year graduation. Eligible students apply in the winter term of their first year when they are taking Calculus I and Engineering Problem Solving II. On-track engineering majors take Calculus II and Engineering Problem Solving III in the spring term of their first year. The summer after acceptance, Fast-Forward participants take Calculus III, Statics and Mechanics of Materials, and Professional Planning with Spatial Visualization [2]. Tutoring is also offered specifically for the Fast-Forward cohort, which is a benefit that students taking these classes during the academic year do not normally receive. The program allows students to get more interaction with the faculty as well as increased interaction with their peers. The program also allows students to take part in local industry visits so that students may see first-hand various engineering workplace settings. Due to COVID-19, the industry visits were virtual for Summers 2020 and 2021. Students participated in Zoom lectures from industry representatives instead of visiting the sites in person. The program consists of roughly twenty students each summer, allowing more one-on-one attention not usually given during the regular academic year. Typical class sizes for Calculus III and Statics and Mechanics of Materials consists of 45-50 students. The program was completely online during Summer 2020 due to the COVID-19 pandemic.

The Professional Planning with Spatial Visualization course involves resume writing, mock interviews, team building, professional communication, and a spatial visualization curriculum called Developing Spatial Thinking [2] [3] [4]. Developing Spatial Thinking is supported by ENGAGE; a project funded by the National Science Foundation that creates resources for Engineering Faculty to use in order to help their students [5]. ENGAGE found that women are outperformed by their male peers in regards to spatial visualization [6]. Before beginning the Developing Spatial Thinking curriculum, participants take the PSVT:R which is referred to as the pre-score. The curriculum covers revolutions, hollow objects, overlapping, cutting, joining, intersecting, projecting, and rotations [7]. A second attempt of the PSVT:R at the conclusion of the course is referred to as the post-score.

The earliest Purdue Spatial Visualization Test consists of three subscales with twelve items each: developments (PSVT:D), rotations (PSVT:R), and views (PSVT:V) [8]. The PSVT:R, used in this study, is a longer thirty-item scale developed at the same time. These instruments focus on measuring an individual's three-dimensional mental rotation ability. Previous implementations of the PSVT:R indicate a possible ceiling effect when it is administered to engineering students [9][10].

2 Project Data

Data collected in this project included a diverse group of participants taking pre and post-tests. A data point was removed due to an unusual score and time taken to complete the test. The participant received a pre score of 30/30 in 17 minutes and 22 seconds, and a post score of 16/30 in 5 minutes and 42 seconds. This decrease of 14 points and the time taken on the post was a clear outlier from the rest of the data. Due to these factors, we decided this participant's data point was not an accurate representation of their abilities, so the point was removed. This participant was a part of the Hispanic males in 2019. In 2021, there was one student who took the tests but requested to not participate in research. Therefore, the student's scores were excluded from the data. Table 1 shows the demographics for the included participants. The number of students in the program in 2020 is lower than the other summers, with only 11 students participating. This is most likely related to the COVID-19 pandemic with the program being completely online. The non-URG students included White and Asian males. The URG students were the rest of the participants who were not a White or Asian male.

Year	Total	Male	Female	non-URG	URG
2017	18	12	6	8	10
2018	17	13	4	10	7
2019	18	10	8	8	10
2020	11	9	2	9	2
2021	16	10	6	7	9
All	80	54	26	42	38

Table 1: Program Participants Demographics

Table 2 shows the percentages of each of these breakdowns.

Year	Male	Female	non-URG	URG
2017	66%	33%	44%	56%
2018	76%	24%	59%	41%
2019	56%	44%	44%	56%
2020	82%	18%	82%	18%
2021	63%	38%	44%	56%
All	67%	33%	53%	47%

Table 2: Percentage Demographics

For the purpose of testing for statistical significance, participants who identify as female, Hispanic, and minority race participants are grouped together as an URG group. Non-Hispanic, White and Asian males were grouped together as non-URG. This created a non-URG group of 42 participants and an URG group of 38 participants, which could be compared against each other due to the similar population sizes.

3 Methods

The following research questions were developed to guide analysis:

- Is there a statistical difference between pre and post-performance for the aggregated data?
- Are there statistically significant changes between pre and post-scores of students from URGs and non-URGs?
- Are there statistically significant differences between students from URG and non-URG in pre-scores? In post-scores?

The grouping of URG participants allowed an assessment of the gender and race questions as well. JASP open-source statistics software is used to run each of the statistical tests used [11]. Paired sample *t*-tests, independent sample *t*-tests, and repeated measure ANOVA (RMANOVA) tests were used to address these questions. All of the tests used in this report use a confidence interval of .95 or 95%. The α value is found from doing 1 - confidence interval. The null hypothesis, H_O, is rejected if the p-value is less than α, thus accepting the alternative hypothesis, H_A. If the p-value is greater than the α, the null hypothesis fails to be rejected. This just means there is not sufficient evidence to make a claim. This does not necessarily mean that the alternative hypothesis is incorrect. The Bonferroni correction must also be applied to each of the statistical tests. The correction is appropriate when conducting multiple statistical tests and involves dividing the α by the number of statistical tests conducted (5 *t*-tests and 3 Repeated Measure ANOVA tests). All inferences were based on an α of .05.

4 Analysis

The preliminary results will be discussed first. The *t*-tests will then be discussed as well as the RM ANOVA tests. All of the paired t-tests are done to test whether the participant's PSVT:R scores increased from pre to post-tests. The paired *t*-tests were run as follows: All, non-URG, URG. Independent samples t-tests were conducted to examine non-URG Pre vs. URG Pre, non-URG Post vs. URG Post. The repeated measures ANOVA tests were run as follows: All, non-URG, and URG. The data was completely de-identified prior to any analysis.

4.1 Descriptive Statistics

Table 3 shows the mean and standard deviations for both pre-test and post-test scores. The data was completely de-identified prior to any analysis. The data comes from the pre and post results of the PSVT:R test discussed previously. The preliminary results show the reason behind running statistical tests. Although we see an increase in scores through observation, statistical significance cannot be claimed until statistical tests are run.

Year	Mean of Pre-Test Scores	Mean of Post-Test Scores	Standard Deviation of Pre-Test Scores	Standard Deviation of Post-Test Scores
2017	21.89	24.28	5.17	3.77
2018	22.35	23.29	4.80	5.47
2019	20.22	22.89	4.43	3.83
2020	19.27	23.73	5.78	4.61
2021	21.31	22.06	5.69	5.50
All	21.14	23.24	5.11	4.61

Table 3: Descriptive Statistics

The number of participants increasing is always more than the number of participants decreasing. There is no clear reason why the students would decrease in score. One reason may just be that the students were not trying on the post-test as no grade was given to the students on how well they performed on the test. We hypothesize that the students are overall increasing for the statistical tests.

Out of all the participants over 2017-2021, most of them scored in the 21-25 range for the pre-test. Out of all the participants over 2017-2021, most of them scored in the 26-30 range for the post-test. Clearly, there is a shift to the higher scores from pre to post results.

4.2 Pre-Test and Post-Test Comparisons

Paired Sample t-tests were performed for all of the students combined, the non-URG students, and the URG students over 2017-2021. Independent Sample t-tests were performed on both the pre scores and the post scores. The α used for t-testing is .01. The results of the Paired Sample t-tests showed that all of the students ($p < .001$), non-URG students ($p = .001$), and URG students ($p < .001$) are increasing from pre to post scores. The Independent Sample t-tests show that URG students scored lower on the pre ($p = .001$) and post ($p = .002$) tests than their non-URG peers. Since most of the data shows skewness, Repeated Measure ANOVA tests were run to support the claims made.

Repeated Measure (RM) ANOVA tests were performed for all of the students combined, the non-URG students, and the URG students over 2017-2021. The α used for RM ANOVA testing is .0167. The RMANOVA test for all of the students combined also showed the difference in rates of increase between the non-URG and URG groups. Results showed that all groups of students are increasing from pre to post scores (All: $p < .001$, non-URG: $p = .003$, URG: $p < .001$), which supports the results of the Paired Sample t-tests. There is no statistical evidence to support a difference in rates of increase between the groups ($p = .414$), which means that the data supports that URG and non-URG students are increasing at the same rate.

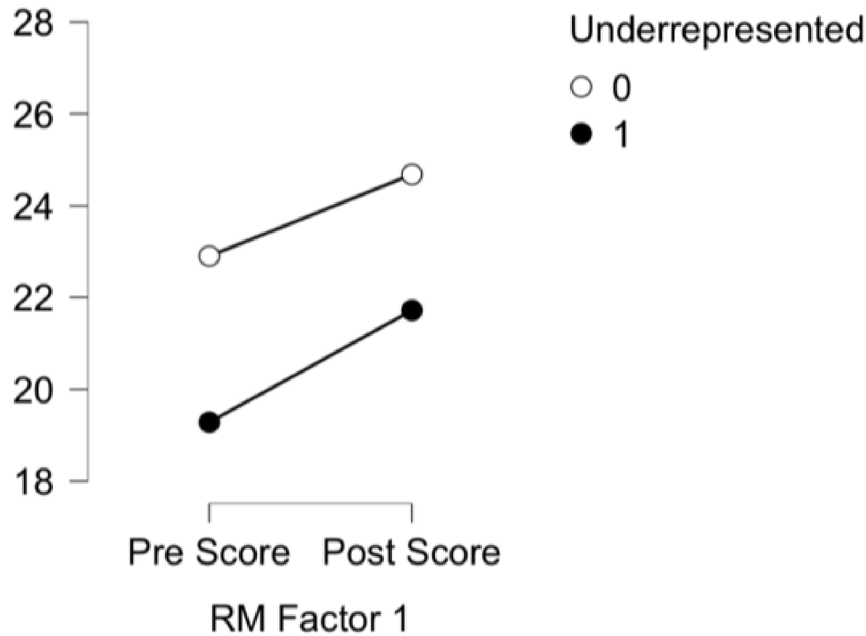

Figure 1: ANOVA Descriptive Data Plot: All

Figure 1 shows the plot of the two groups (0: non-URG and 1: URG) score increases. Both lines are clearly increasing as seen by their positive slope, which represents the statistical significance between pre and post results for all of the data combined discussed previously. The lines are not increasing at different rates, which supports the claim made by the lack of statistical difference between subject factors discussed previously. To see a statistical significance here we would need to see the lines have a greater difference in slope.

5 Conclusions and Future Directions

There is a statistical significance in the difference between pre and post-results for all three groups discussed: all of the participants combined, only the URG participants, and only the non-URG participants. The URG participants have slightly larger effect sizes than the non-URG participants, but no statistical significance can be seen between the groups' difference in rate of increase. The URG students are statistically scoring lower than non-URG students on the pre and post-tests. The results suggest that although the program is helping all students increase overall, the program is not helping URG students score at the same level as non-URG students on the post-test. The claims made by ENGAGE in regards to the Developing Spatial Thinking curriculum discuss closing the gap between URG and non-URG groups, but the data seen in this paper shows otherwise. The Engineering Fast-Forward Program will have one more summer of students, so these results could change.

Acknowledgments

This material is based upon work supported by the National Science Foundation (NSF) under Grant No. 1564768. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

References

[1] Sophomore fast-forward: A summer bridge program to support retention in engineering. Accessed = 2021-05-10. URL: https://www.nsf.gov/awardsearch/showAward?AWDID = 1564768HistoricalAwards = false.
[2] K. Evans, M. Desselles, and M. K. Orr, "Year 2 of an S-STEM summer scholarship for a sophomore bridge program," presented at the ASEE Annual Conference & Exposition, Tampa, FL, 2019. [Online]. Available: https://peer.asee.org/32357.
[3] K. Evans, M. K. Orr, D. E. Hall, and M. Desselles, "S-stem summer scholarship for a sophomore bridge: Year 1 in review," presented at the ASEE Annual Conference & Exposition, Salt Lake City, UT, 2018. [Online]. Available: https://peer.asee.org/30020
[4] K. Evans, M. Desselles, and M. K. Orr, "Year 3 of an S-STEM summer scholarship for a sophomore bridge program," presented at the ASEE Annual Conference & Exposition, Virtual, 2020. [Online]. Available: https://peer.asee.org/35713
[5] Engage: Engaging students in engineering. Accessed = 2021-05-10. URL: https://www.engageengineering.org
[6] S. Metz, S. Sorby, J. Moosbrugger, P. Saboori, R. Goff, and P. Campbell, "Implementing ENGAGE strategies to improve retention: focus on spatial skills: engineering school discuss successes and challenges," presented at the ASEE Annual Conference & Exposition, Vancouver, BC, 2011. [Online]. Available: https://peer.asee.org/18100
[7] "*Higher Education Services: Visualizing Success*." https://www.higheredservices.org/ (accessed: Jan 31, 2022).
[8] R. Guay, *Purdue spatial visualization test*. West Lafayette, IN: Purdue Research Foundation, 1976.
[9] J. V. Ernst, W. T. O., A. C. Clark, and D. P. Kelly, "Factors of spatial visualization: an analysis of the PSVT:R," Engineering Design Graphics Journal, vol. 81, no. 1, 2017.
[10] J. V. Ernst, T. O. Williams, A. C. Clark, and D. P. Kelly, "Psychometric properties of the PSVT:R outcome measure: a preliminary study of introductory engineering design graphics," presented at ASEE Annual Conference and Exposition, Daytona Beach, FL, 2016. [Online]. Available at https://Peer.asee.org/30120
[11] JASP Team. 2021. Jasp, ver. 0.16 [Online]. Available: https://jasp-stats.org/
[12] J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*. New York, NY: Routledge, 1988.