A Journey to Integrate Spatial Visualization into Community College Engineering and Technology Programs to Increase Student Diversity and Retention

Mr. Kenneth Paul Grimes, Tidewater Community College

Kenny Grimes is an Associate Professor of Engineering at Tidewater Community College in Virginia Beach, VA. TCC's Associate of Science in Engineering program produces transfer students that comprise nearly half of the Old Dominion University engineering undergraduate population. Mr. Grimes' TCC position is a culmination of diverse prior experiences from careers as a powertrain control system engineer at General Motors, a program director at SpringHill camp, and an urban public high school math and physics teacher and F.I.R.S.T. robotics team #1793 coach. He is recipient of TCC's 2015 Faculty Reward for Professional Excellence in Teaching, is a 3-time Norfolk Public Schools Bell Award winner, a Norview High School's Teacher of the Year finalist, a General Motors Sloan Fellow, and co-author of a 'Best Paper" at the 1987 International Symposium on Automotive Technology Association, Florence, Italy. He earned a M.S. in Education from Ferris State University, a M.S. in Engineering from Purdue University, and a B.S. in Electrical Engineering from Kettering University. Mr. Grimes has also been an ASEE Two-Year College Division, Robot Competition - Judge, and Team Co-Sponsor from 2012 to the present.

Ms. Sally Wells Daniel, Tidewater Community College

Sally Wells Daniel received a Bachelor's Degree in Psychology and Philosophy from Centre College of Kentucky and a Master's Degree in Community Psychology from Wichita State University. She became interested in the lack of women in STEM careers while working at The Women's Center at Tidewater Community College. She first engaged women in career technical education and met with success in increasing the numbers of women in the school's welding program. She also began studying why the number of women engineers had not risen in the same proportion as it had in other non-traditional professional careers. This research brought her to the disparity of spatial visualization intelligence between women and men. She transferred into the Engineering Department as the Coordinator of Recruitment and Retention at the community college, working with faculty and students to devise a way to increase spatial visualization in all students who wanted to be engineers. Ms. Daniel was instrumental in securing a grant from the American Association of University Women to create a one-day hands-on STEM conference for 100 middle-school girls and their parents in 2014. Since receiving that grant, the Virginia Beach Branch of the AAUW has continued planning and implementing this conference. Ms Daniel is in her second term of presidency of this branch.

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Introduction

Spatial cognition, or spatial visualization, is the type of intelligence one must have to generate and rotate objects mentally. Females were found to score lower on this type of intelligence, causing an incorrect assumption that the brains of females were not “wired” for careers reliant on spatial visualization. This assumption was disputed by Feng, Spence and Pratt (2007) when they showed that playing an action-styled video game (*Medal of Honor: Pacific Assault)* for 10 hours over four weeks improved spatial cognition in both men and women and eliminated the previously-found statistically significant gender difference as measured in a standard test of mental rotation (Mental Rotation Test).

At the same time, Sheryl Sorby, an engineering professor at Michigan Technological University, used her own experiences with a deficiency of spatial visualization to notice that many of her students (particularly women) also struggled with this deficiency. She began to offer classes in spatial visualization to her students and found that her engineering students responded with better spatial skills with minimal rudimentary, focused practice on rotations (Sorby, 2001; Sorby, 2009).

With these pioneering studies as a guide, the Women’s Center at Tidewater Community College (TCC) spearheaded a spatial visualization training program as an effort to increase the number of female students enrolled in engineering. As a new program, we had to demonstrate (1) such training would be beneficial in the retention of our engineering students and (2) could be be offered with minimal use of resources. Over 14 semesters TCC investigated several methods and formats to structure such a program (see Figure 1).

The variety of methods reflects attempts to balance the two objectives above, with the political administrative landscape at TCC toward adopting spatial visualization into curriculum requirements. If the benefits could be shown, would spatial visualization become a required skill assessment tool, like existing math placement tests? Or would spatial visualization fit better a required 1-credit course? Despite impressive results, organizational support did not materialize at TCC to either of these policy changes. Instead, the researchers found least resistance (and satisfactory benefits) with integrating the spatial visualization training into an existing 1-credit student orientation course (SDV-101) that is required for both engineering and technology.

Figure 1. Spatial Skills Training at Tidewater Community College

		Target Audience	Assessment	Eligibility	Intervention
Phase 1	Spring 2009 Summer2009 Fall 2009 Spring 2010	Engineering Graphics (EGR 110)	Pre: Mental Rotation Test (Form A) Post: MRT(B)	<13 of 24 (or <54%)	*Medal of Honor: Pacific Assault*, 10 hours over four weeks
Phase 2	Spring 2011	Engineering Graphics and Introduction of Engineering (N= 88), and all with engineering major (N=166)	Same as above.	Men <14of24 (or <58%) Women – any score	11 one-hour weekly sessions training sessions with Sorby workbook and web-based materials (2003, 20008) and lunch
Phase 3	Fall 2011	EGR 110 or 120	Same as above.		Sorby curriculum same as Phase II, 10 sessions offered in two different time slots with snack, not lunch;
	Spring 2012	Same as above.	Same as above.		10 hours of training in four 2.5 hour sessions
	Fall 2012	Same as above.	Same as above.	< 15 of 24	Same as Spring 2012
	Spring 2013	EGR 110	PSVT:R	30 questions	five 2.5 hour training sessions with time for 'homework' in class
Phase 4	Fall 2014 Spring 2015	EGR110 Add entry level, graphics-based courses in Architecture Technology, CAD Technology, Civil Engineering Technology, Electronics Technology	Same as above.	<18 of 30 (or <60%)	Same as above
	Fall 2015, Spring 2016	Same as above.	Same as above.	<21 of 30 (or <70%)	five 2-hour sessions; flipped format – review of online materials at home, solving problems and sketching in face-to-face training sessions
Phase 5	Fall 2016	All engineering and technology students, even before enrolling into graphics-based courses.	Same as above.	Same as above.	Continued flipped format. Only 8 hours of course material (instead of 10) within required 1-credit SDV101 orientation course for engineering and technology students.
	Spring 2017	Same as above.	Same as above.	Same as above.	Continued flipped format. Condensed course material further from 8 down to 6 hours of training sessions within SDV 101.

Phase 1—Spring 2009, Summer 2009, Fall 2009, Spring 2010

Method: Students enrolled in Engineering Graphics (EGR 110) were given the Mental Rotation Test (Form A) (Laeng, B., Latham, K., Jackson, M., Zaiyouna, R. & Richardson, C., 1995), during the first weeks of the semester. The students who scored less than 13 (out of 24) were invited to participate in an intervention, playing *Medal of Honor: Pacific Assault*, for 10 hours over four weeks, a video game shown to increase spatial skills (Feng, Spence and Pratt, 2007). We retested all students -- those who participated in the intervention, those who refused to participate in the intervention, and those who did not need the intervention—at the end of the semester using Form B of the Mental Rotation Test.

Results: We found initial spatial deficiencies in 79% of female students (39% of all students) tested. We noticed interesting findings for the 14% of those with deficiencies (both genders) who completed this voluntary program. All students who completed the program completed the course. In contrast, 56% of students with initial spatial deficiencies who did not complete the intervention program withdrew from class. The mean grade of those with deficiencies who completed the program was higher than the class average as a whole.

Discussion: Although the findings looked promising, the low number of students voluntarily participating in the intervention did not allow us to analyze the results with inferential statistics. The result that 56% of students who did not have the prerequisite spatial skills dropped this gateway class to the Engineering program was impressive and worth continued attempts to validate the effectiveness of the intervention at addressing the problem of low spatial intelligence in entry-level engineering students.

Phase 2—Spring 2011

Method: Using a Campus Action Program Grant from The American Association of University Women, we restructured our intervention and replaced the video gaming approach with a series of training sessions using the workbook and web-based materials developed by Sheryl Sorby (2003, 20008).

We tested students in Engineering Graphics and Introduction of Engineering (N= 88) using the MRT-A during the first weeks of the semester. Thirty-six (47%) of the male students and all 11 female students (nine of whom scored at or below 14 correct out a possible 24 questions on the test) were invited to participate in the intervention program. In a further attempt to increase the number of women in the program, all females who had declared engineering as their program (N=166) were invited to participate in the program. Of these women, eight took the MRT-A, with no woman scoring over 14 on this test.

The intervention was a series of 11 one-hour weekly sessions. In order to entice completion of the course, we offered lunch to participants during class time. We also split the class into gender-specific dyads (or work pairs) as a way for students to get encouragement from one another. An engineering professor attended all sessions and led introductory exercises. In addition, Engineering students were in the classrooms to support students, grade homework and answer questions.

All students were retested using the MRT(B) at the end of the semester.

Results: The results from this revised method are summarized in the following chart.

Category of Student	Number	Increase in MRT scores from pre- to post-test	Retention Rate	Final Grade in Engineering Course
Males – eligible, completed program	9	8 (33%)	89%	2.87
Males – eligible, refused program	27	3.6 (15%)	70%	2.57
Males – not eligible	41	3.29 (13.8%)	80%	2.8
Females enrolled in EGR 110 or 120 and finished program	4	5.25 (21.9%)	75%	3.0
Females refused program	7	6 (25%)	75%	2.67
Females not in EGR 110 or 120 finished program	8	0.63 (2.6%)	N/A	N/A

Discussion: We found that 84% of female and 47% of male students entering the engineering program had low skills in spatial visualization. Males and females who completed the 11-week program to practice these skills increased scores on the post-test participate. The semester grades of program, completers were higher than the grades of those who were initially more prepared. The most striking result was the retention rate for male students. Male students who had low initial spatial skills and completed the program had a 19% higher retention rate than men with similar scores who did not participate in the program.

Women who were not registered in EGR 110 or 120 did not make significant progress in spatial visualization intelligence. One hypothesis for this result is that these students did not have a chance to put their new-found knowledge to use in another class and thus did not practice the skill to the level of competence.

Although we continued to find an initial lack of buy-in for this program (only 10 out of 36 males and four out of 11 females in the classes voluntarily accepted the free training offer), fewer students dropped out of this more structured program, we posit that the addition of a free lunch and intentional pairing of students led to a greater incentive to finish the program.

Using these findings, we entered Phase 3 of our journey to find a better way to deliver remedial spatial visualization training.

Phase 3—Fall, 2011

Method: We changed our selection process to include only those students in either EGR 110 or 120. We continued to use the MRT as our pre- and post-test and Sorby's material to present the material. Due to lack of funding, we offered snacks instead of lunch during the sessions. In an attempt to make this an easier commitment, we offered the sessions at two different time slots during the week for 10 weeks. Professor Kenny Grimes assumed the instructor role for one of the weekly time slots, and Professor David Ekker continued as instructor for the other.

Results: Fifty-seven students, 32% of all students tested, were "eligible" for inclusion in the program based on low scores on the MRT (A). Of the eligible students, only 15 (26%) volunteered for the program (eight females and seven males) and eight completed the program. Because of the low numbers, rather than analyze the results, we attempted to gain an understanding of how the program did or did not meet the needs of the students.

We found that that the majority of students found the majority of the Sorby training modules as very helpful. Students rated the workbook, professor, and student helpers to be integral to their success. Student ratings indicated that the program made engineering class work easier (average: 8.4 on a 10 point scale), and increased confidence to continue in the engineering program (average: 8.7 on a 10-point scale). Eight out of nine respondents stated that they would recommend this class to other engineering students.

Discussion: As in the past, it was difficult to entice students to take this voluntary program. Students had a variety of reasons for not attending this additional weekly class, including class conflict, employment, family obligations, and willingness to admit that they needed the program. Even offering sessions at two different times did not seem to help recruitment. We also experienced a large increase in drop-outs this semester. We speculate that not having external incentives (food) was, at least, a factor in this increase.

Spring 2012

(10 hours of training now conducted in four 2.5 hour sessions)

Method: We continued with the same method of selecting students; however, we shortened the program to run for only 4 weeks (2 ½ hours per week) to reduce student inconvenience, especially for working and commuting students. An added benefit to the 4 week schedule was that students could gain and immediately apply skill and confidence to their engineer graphics course sooner than with a 10-week program, and reap benefits in that course. Kenny Grimes became the sole instructor for all training sessions.

Results: We again found that of the total 133 students (20 females; 113 males) given the pre-test, females were more likely to need the spatial visualization program although a significant number of males also "tested into" the program (53% female; 25% male). However, we continued to have difficulty in getting students to voluntarily enroll and complete the program. Of the 39 students eligible, only three females (35%) and seven males (25%) accepted. Two males dropped from the training without completing the program.

Category of Student	Number	Change in MRT scores from pre- to post-test	Retention	Final Grade in Engineering Course
Males - eligible, enrolled	5	6.8 (28%)	0 withdrawals (0%)	3.4
Males – eligible, not enrolled	23 (14 did not take post-test)	3.2* (13%)	2 withdrawals (10%) **	2.7 (2.5 when withdrawals included)
Females – eligible, enrolled	3	4 (17%)	0 withdrawals (0%)	3.3
Females – eligible, not enrolled	8	-1.7 (-7.1%)	2 withdrawals (9%)***	1.9 (1.5 when withdrawals included)
Females - not eligible	9		0 withdrawals (0%)	3
Males - not eligible	85		12 withdrawals (15%)****	3.5 (3.1 when withdrawals included)

*based on 9 students—14 did not take post-test
**based on 21 students since 2 dropped during the initial drop period (the class does not show on their transcript) but after pre-test
***based on 6 students since 2 dropped during drop period but after pre-test
****based on 80 students since 5 dropped during drop period but after pre-test
Keep this line. Do we need the other disclaimers?

Discussion: Similar to the results of previous semesters, eligible males who complete the spatial visualization program out-performed their counterparts who do not complete the program in MRT scores, retention rates, and engineering class grades. Females who volunteered for the class out-performed their counterparts who do not complete the program, earning a “C” (transferrable grade) rather than a “D” (non-transferrable grade) in the course. Further, we continued to find that eligible students who took the program were less likely to withdraw from the course. One explanation for this result is that students who volunteer for extra work demonstrate persistence that also makes them less likely to give up on the course. An alternative explanation is that the program volunteers are more prepared for class because of the course preparation, and thus do not become as frustrated as those who do not have the extra help.

We found that accelerating the class from 10 weeks to four weeks decreased the drop-out rate but continued to impact retention and grades as well as in the previous 10-week training used in the past seven semesters.

Fall 2012

(raised maximum score permitted for training from 14 to 15)

Method: We used the same method as in Spring 2012, keeping the accelerated four-week program schedule. However to match other schools that conduct similar programs, we raised the criterion for eligibility from 14 to 15 or below correct out of a possible 24 questions.

Results: We pre-tested 57 students: five females (9%) and 52 males (91%). Of those who scored 15 or below on the MRT(A), four were female (80%) and 26 were male (50%). Of the low scorers, one female (25%) and 12 males (46%) accepted our invitation to participate in the spatial visualization program. Of these, two males and the lone woman dropped from the program before training was complete.

Category of Student	Number	Change in MRT scores from pre- to post-test	Retention	Final Grade in Engineering Course
Males - enrolled	10	4.5* (or 18.8%)	2 withdrawals (25%)	1.6
Males – eligible, not enrolled	16	6.6**(or 27.5%)	4 withdrawals (25%) **	2.7
Females - enrolled	0	--	--	--
Females – eligible, not enrolled	4	5***(or 20.8%)	1 withdrawal (25%)	1.3
Females - not eligible	1	+	0 withdrawals (0%)	0
Males - not eligible	27	+	5 withdrawals (19%)****	1.8

*based on 8 students—2 did not take post-test
**based on 10 students who took both pre- and post-tests
***based on the 2 students who took both pre- and post-tests
+not deemed relevant due to high scores on initial test

Discussion: Again we found a significant portion of our students (over 50%) with poor spatial skills. Obviously, we captured more students by raising the eligibility standard by one point; however, looking at the low final grades in every category of student shows that these students seem to be less able to complete the work of the class. Withdrawals were significantly higher than other semesters.

This was the first time that eligible males who refused the program out-scored both the eligible males in the program AND males with initial high spatial skills. Since we did not change the nature of the program or the instructor, we can offer no explanation for the results.

Spring 2013
(Switched from MRT to PSVT:R assessment tool)

Method: We used the same methodology as fall 2012, with the two following exceptions. First, we expanded from four training sessions to five 2.5-hour training sessions to allow students more time to do the 'homework' in class to increase the poor homework completion rates of the past. Second, we changed the pre and post assessment from the MRT to the Purdue Spatial Visualization Test, Revised (PSVT,R) to align our program with other schools' efforts. The web-based PSVT:R assessment requires only 20 minutes to respond to 30 questions and can be taken in class or completed as a homework assignment.

Results: We tested 81 out of the 88 students enrolled in EGR 110. Seven students either refused to take the test or enrolled in the class after late. Of these 81, 13 students scored 16 or below on the 30-question PSVT,R. Although we attempted to make this program appealing (three different sections at various times; conducting training early in the semester and relaying results for past students' success), only eight of the 13 (62%) volunteered to take—and subsequently finished—the program. No women volunteered for the program.

Category of Student	Number	Change in PSVT:R scores from pre- to post-test (30 questions)	Retention	Final Grade in Engineering Course
Eligible - completed program	8	6 (or 20%)	2 withdrawals (25%)	2.67
Eligible - did not enrolled	5	-4 (or -16.7%)	2 withdrawals (40%)	1.7
High scorers	68	*	8 withdrawals (12%)	3.0

*not seen as relevant since many of the initial scores were close to the maximum score cannot achieve the same change in their score

Discussion: The results of this pre-test were surprising. When using the MRT, 30% of the tested students qualified for the program, but only 15% of students who tested with the PSVT:R were eligible. This could be due to several factors. First, there was a misunderstanding of the PSVT:R time limit and students were permitted more than the 20 minutes suggested to respond to the PSVT:R. An additional impact could be the digital format of the PSVT:R compared to the paper and pencil format used in previous semesters with the MRT. Another possible contributing factor could have been an atypically well-prepared student pool. The pass rates of the PSVT:R were never this high again in any later semesters.

Females scored dramatically better on this test than on MRT used in the past: only three of the 10 women (30%) tested earned scores less than 15. However, this number represents 27% of the eligible students even though the sample size included only 12% females. Thus, females continue to be over-represented in low spatial scores.

One bit of good news for this semester's program was that nobody dropped out of the training program. Thus, although we had fewer volunteers, we kept those students throughout the program.

Again, eligible students who completed the spatial visualization program performed better than eligible students who did not volunteer for the program. They ended the engineering class with almost a full point difference in their course grade—again making the difference between a transferrable credit and a non-transferrable credit.

Phase 4: Fall 2014, Spring 2015

(technology students added)

Method: We broadened the research to include technology students by joining the Stevens Institute ATE grant "Adapting Tested Spatial Skills Curriculum to On-Line Format for Community College Instruction: A Critical Link to Retain Technology Students." The student pool this semester included the existing EGR110 student pool, as well as students enrolled in entry level, graphics-based courses in the Architecture Technology, CAD Technology, Civil Engineering Technology, or Electronics Technology programs. These new students were working for certification, or an Associates degree in Applied Science.

Students who earned a score lower than 18 correct out of 30, below 60%, were invited to the training and with the additional funding, the technology students were offered a $115 stipend for successful completion.

In spring of 2015, the PSVT:R assessment time was reduced to the suggested 20 minutes, which allowed more students to receive and benefit from the spatial visualization training and aligned our practices with those of our grant partners.

Results:

Category of Student	Number Fall'14 / Spr'15*	Increase in PSVT:R scores (from pre- to post-test (30 possible)	Retention Rate	Final Grade in EGR or Tech Course
students tested	149 / 142			
Ineligible students scoring 18 or higher out of 30	88 / 93	-0.24 pts (or -0.8%) for 34 students who took both pre and post	13.7% failure (12 D or F)	2.8
eligible students scoring 17 or lower out of 30	69 (46% Fall '14) 50 (35% Spr'15)		26% failure (12 D or F) (6 withdrawals)	
Eligible students who declined workshops	52 (of 69 eligible)	-1.2 pts (or -4.0%) for 9 students who took both pre and post		2.6 (excludes 6 withdrawn)

attended at least one session	16 (or 23% of students invited to training)			
completed spatial viz training workshops	9 (or 56% of workshop attendees)	+2.0 pts (or +6.7%) for 3 students who took both pre and post	11% (1 D grade)	3.0**

*for spring2015 only pre-PSVT:R scores reported at this time.
**1 student added to this data. She dropped EGR110 after failing pre-PSVT:R, but completed the workshop training. This student then re-enrolled in EGR110 in following semester and earned a 'A' in the course.

Discussion:
We again saw a discouragingly low volunteer participation rate. We also had difficulty in managing the reach of the research across so many sections of so many courses. Instructor buy-in and endorsement was crucial to the success of student recruiting.

Fall 2015, Spring 2016

(flipped format of training sessions)

Method: We shortened the training time to five 2-hour (rather than 2.5 hour) sessions to make it more appealing to students. Also, because homework completion rates were still unsatisfactory, we 'flipped' the classroom format so that students reviewed the online Sorby materials at home on their own and engaged in structured homework help during the face-to-face sessions. Thirdly, students who scored less than 70%, fewer than 21 of 30 correct on the PSVT:R were invited to the training. This score was supported by research and would also generate a larger student pool for research data, as the volunteer participation continued to be low.

Results:
Further data and analysis are pending. Right now we can only say:

Category of Student	Number 389 student pool (89 not tested)	Increase in PSVT:R scores (from pre- to post-test (30 possible)	Retention Rate	Final Grade in EGR or Tech Course
students tested	300		*	*
Ineligible students scoring 21 or higher out of 30	164 (55% of 300)	0.43 (or 1.4% for 60 students who took both pre and post test)	*	*
eligible students scoring 20 or lower out of 30	136 (45% of 300)		*	*
Eligible students who declined workshops	100 (74% of 136)	4.0 (or 13% for 30 students who took both pre and post test)	*	*
attended at least one session	36 (26% of 136)		*	*

completed spatial viz training workshops	16 (44% of 36)	3.8 (or 13% for 18 students who took both pre and post test)	*	*

*Only pre and post PSVT:R reported at this time.
**9 of 16 completers from engineering, 7 of 16 from technology programs

Discussion:
Discouraging low volunteer participation rate continues. Faculty colleagues cooperated, but didn't fully understand the value of this program to retain students and improve the diversity of the student population. There is not sufficient organizational willpower to adopt the PSVT:R assessment at a placement into entry level engineering and technology programs. Also lacking is support to create or require a developmental 1-credit hour course of spatial visualization training. It is not clear how much longer we can afford work so hard to help so few.

Phase 5: Fall 2016

(participation in training now required within SDV101 orientation course)

Method: The significant change in the course format this semester was precipitated by a loss of man power, which was required in previous semesters to identify and recruit eligible volunteers through emails, telephone calls, and cajoling. Given the personnel change and the fact that in previous semesters such a large percentage of students had been eligible for the program, instead of asking for voluntary participation, the course material was integrated into a required 1-credit hour orientation course for engineering and technology students. No longer would we have to recruit students for the program. However, since some of the existing course content needed to be retained, we did not cover two of the course modules. Further, since the material was embedded into a required course and the stipend had not been a particularly effective recruiting tool or a motivator for course completion, the stipend was not offered.

Results:

Category of Student	**Number 81 student pool (5 dropped)**	**Increase in PSVT:R scores (from pre- to post-test (30 possible)**	**Retention Rate**	**Final Grade in EGR or Tech Course**
students tested	75 pre-PSVT:R 67 post-PSVT:R	23.6 - 20.2 = 3.4 pts (or 11% for 67 students who took both pre & post)		n/a
Spatially prepared students scoring 21 or higher out of 30	41 (55% of 75)	1.19 pts (or 4.0% for 36 students who took both pre and post)	83% (7 D or F in course)	n/a (as many not yet in this kind of course) 3.00
Spatially under prepared students	34 (45% of 75)		74% (9 D or F in course)	n/a (as many not yet in this

scoring 20 or lower out of 30				kind of course) 2.79
Eligible students who declined workshops	n/a (but 4 students failed to attend class and/or submit HW)			n/a
attended at least one session	not applicable			n/a
completed spatial viz training workshops	30 (88% if 34)	+5.73 pts (or +19.1% for 30 students who took both pre and post)		n/a

Discussion:
This change in training format presented a set of challenges. After 6 years of consistent impact on retention and success, the most significant question was whether we would see similar outcomes with required training yet reduced training time. Also in question, whether a classroom with a full range of spatial skills is as effective as the protective setting of the past with only low-scoring students in the room. We took a calculated risk that the spatially accomplished students would not sour the learning environment for students in need of remediation in spatial visualization skills. The fact that the material was required for all students eliminated the ability to compare eligible training students who completed the program with counterparts who declined training. Also, we are not able to compare students' grades in graphics based engineering or technology courses, as many students were not yet enrolled in such courses.

Finally, the interest of the ATE grant is in the success of our technology students. However, it is becoming more difficult to distinguish the engineering student from the technology student. Nearly one-half of students who enroll in engineering at TCC eventually migrate into the technology programs, or leave for a business, IT, or general science certification or degree. This distinction issue is more prevalent with students in the orientation course in which we have embedded the spatial skills program, a course required within the first 15 hours of academic record. In past semesters, students were enrolled in engineering and technology program courses. In an SDV101 orientation class, some students could be taking the spatial visualization training two or more semesters prior to students in past semesters of research.

Spring 2017

Method: Continued the required course material in a required SDV101 engineering and technology orientation course. However, only 6 hours of training sessions were spent on spatial visualization. Seven of the ten modules of Sorby's materials were combined into three of the training days. That is, seven modules will be given less than half of the time and attention as in the past semesters. Three other modules will be given their normal 1 hour of training time.

Results:
Results expected in May, 2017.

Discussion:
Not available until data and analysis are complete.

Conclusions

We found a significant percentage (approximately 40%) of our engineering and technology students entered our programs with deficits in their spatial reasoning skills. All intervention methods used benefitted students who participated in a remedial spatial visualization training. Students of both genders who took the spatial visualization training program dropped out of their engineering/technology courses less frequently, and even outperformed those who initially had good spatial skills (in some cases). We have not encountered many intervention strategies show such dramatic results in retention and grades.

Non-participating spatially under-prepared students suffered the consequences of decreased retention and decreased grades in spatially-based engineering/technology courses. Further data mining will quantify the observation that this spatially underprepared group is over-represented with women and students of other non-traditional socio-economic status.

We found ways to assess the spatial intelligence of our students easily and inexpensively.

However, enticing students to participate in a "voluntary" program is problematic. Some students do not perceive that they need help with spatial visualization. Other students cannot (or will not) fit extra sessions at school into their schedule for spatial visualization training. Even offering $115 stipends did not impact participation rates. The low level of voluntary participation is shown below.

Year	Number of students pre-tested	Number of students invited to workshops (low spatial visualization scores)	Number of Workshop Participants (that completed workshops)
2009-10	236	104	13
Spring 2011	96	55	21
Fall 2011	178	57	15
Spring 2012	133	39	8
Fall 2012	57	30	10
Spring 2013	81	13	8
Fall 2013	n/a	n/a	6
Fall2014 - Spring2015	143	55	9
Fall2015	183	81	9
Spring2016	117	58	7
Fall 2016 (5 sections of SDV101 course)	76	34	28
Spring 2017 (3 sections of SDV101 course)	n/a	n/a	n/a
TOTALS	1300	526	126

We found two strategies that helped enrollment. One is to provide a full lunch during the program sessions. The other is to include these sessions within a required introductory course.

However, as the variety of training strategies shows, finding a way to get students to volunteer to receive help has led us to instead include it as a portion of a mandatory class. We emphatically recommend spatial visualization training be made a required content of curriculum early in the engineering and technology tracks, and do not recommend a voluntary training format.

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