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Multi-Disciplinary Summer Orientation Sessions for First-Year Students in Engineering, Engineering Technology, Physics, and Computer Science

Dr. Clara Novoa, Texas State University - San Marcos

Dr. Clara Novoa is an Associate Professor at the Ingram School of Engineering at Texas State University. She has a Ph.D. in Industrial Engineering and her research areas are Dynamic and Stochastic Programming and Parallel Computing to solve mathematical optimization problems applied to logistics and supply chain. Dr. Novoa has 15 years of experience in academia and 4 years of experience in industry. Dr. Novoa is receiving funding from NSF through SPARK and Texas State STEM Rising Stars. SPARK is a four years grant that looks to increase the recruitment and retention of female in engineering, computer science, and related fields by providing scholarships for low-income and talented students. Texas State STEM Rising Stars is a four years grant committed to increase the first and second year retention and graduation rates of students in STEM. Dr. Novoa is also the advisor of the Society of Women Engineers. She is committed to research on strategies to achieve gender equity and cultural inclusiveness in science and engineering.

Dr. Araceli Martinez Ortiz, Texas State University - San Marcos

Araceli Martinez Ortiz, Ph.D., is Assistant Research Professor of Engineering Education in the College of Education at Texas State University. Araceli is also director of the LBJ Institute for STEM Education and Research where she collaborates on various state and national STEM education programs and is PI on major grant initiatives such as the NASA Educator Professional Development Collaborative and NSF Texas State STEM Rising Stars. Araceli holds Engineering degrees from The University of Michigan and Kettering University. She holds a Masters degree in Education from Michigan State and a PhD in Engineering Education from Tufts University. Her research interests include studying the role of engineering as a curricular context for mathematics and science learning in K-20 and developing research-based active-learning instructional models and assessment instruments to enhance engineering students' learning experiences and STEM teacher professional development. She works with teachers, families, and students from underrepresented communities.

Dr. Kimberly Grau Talley P.E., Texas State University

Dr. Kimberly G. Talley is an assistant professor in the Department of Engineering Technology, Senior Research Fellow and Maker Space Co-Director for the LBJ Institute for STEM Education and Research at Texas State University, and a licensed Professional Engineer. She received her Ph.D. and M.S.E. from the University of Texas at Austin in Structural Engineering. Her undergraduate degrees in History and in Construction Engineering and Management are from North Carolina State University. Dr. Talley teaches courses in the Construction Science and Management Program, and her research focus is in student engagement and retention in engineering and engineering technology education. Contact: kgt5@txstate.edu

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Abstract

This work in progress is motivated by a self-study conducted at Texas State University. The study revealed that the average second year science, technology, engineering and math (STEM) student retention rate is 56% vs. 67% for all majors, and that 16% of STEM majors are female while 57% of all undergraduate students are female. Using these statistics, the authors identified the need to offer motivating experiences to freshman in STEM while creating a sense of community among other STEM students. This paper reports on the impact of two interventions designed by the authors and aligned with this need. The interventions are: (1) a one-day multi-disciplinary summer orientation (summer15) to give participants the opportunity to undertake projects that demonstrate the relevance of spatial and computational thinking skills and (2) a subsequent six-week spatial visualization skills training (fall 2015) for students in need to refine these skills. The interventions have spatial skills as a common topic and introduce participants to career applications through laboratory tours and talks. Swail et al.[1] mentions that the three elements to address in order to best support students' persistence and achievement are cognitive, social, and institutional factors. The interventions address all elements to some extent and are part of an NSF IUSE grant (2015-2018) to improve STEM retention.

The summer 2015 orientation was attended by 17 freshmen level students in Physics, Engineering, Engineering Technology, and Computer Science. The orientation was in addition to "Bobcat Preview", a separate mandatory one-week length freshman orientation that includes academic advising and educational and spirit sessions to acclimate students to the campus. The effectiveness of the orientation was assessed through exit surveys administered to participants. Current results are encouraging; 100% of the participants answered that the orientation created a space to learn about science and engineering, facilitated them to make friends and encouraged peer interaction. Eighty percent indicated that the orientation helped them to build confidence in their majors. Exit survey findings were positively linked to a former exit survey from an orientation given to a group of 18 talented and low-income students in 2013.

The training on refining spatial visualization skills connects to the summer orientation by its goals. It offers freshman students in need to refine spatial skills a further way to increase motivation to STEM and create community among other students. It is also an effective approach to support students' persistence and achievement. Bairaktarova et al.[2] mention that spatial skills ability is gradually becoming a standard assessment of an individual's likelihood to succeed as an engineer. Metz et al.[3] report that well-developed spatial skills have been shown to lead to success in Engineering and Technology, Computer Science, Chemistry, Computer Aided Design and Mathematics. The effectiveness of the fall 2015 training was assessed through comparison between pre and post tests results and exit surveys administered to participants. All participants improved their pre-training scores and average improvement in students' scores was 18.334%.

Motivation and background

Texas State University is a public, student-centered, emerging research university with almost 38,000 students. The university is a Hispanic Serving Institution where ethnic minorities make up 49% of the student body and 33% are Hispanic. A self-study conducted in Fall '13 revealed that second year STEM retention rate is 56% vs. 67% for all majors, 16% of STEM majors are female while 57% of undergraduate students are female, and second year retention for Hispanics and African Americans is 46% vs. 60% for white. In Spring'15, the authors and six other faculty in the College of Science and Engineering were awarded a four-years grant from the NSF - IUSE program (Jan 1, 2015 – Dec 31, 2018) with the goals of producing significant improvements in freshman and sophomore retention rates in *Chemistry, Computer Science, Engineering, Engineering Technology, Mathematics and Physics* and increasing the number of female, Hispanic and African American students completing undergraduate degrees in these STEM fields.

The funded NSF - IUSE project comprises the following strategies and supporting activities:
1. Improve instruction by (a) establishing a STEM education active learning faculty summer institute and quarterly brown bag and (b) redesigning introductory CS courses.
2. Establish early and motivating field-of-study and career explorations for students through a) Summer Orientation Sessions for first-year STEM students and b) a first-year introductory course in Engineering and Engineering Technology.
3. Foster meaningful student engagement experiences into the professional community by (a) offering guided internships for second-year students in Engineering and Engineering Technology and b) enhancing student mentoring and social and educational activities and recruitment.
4. Support student academic learning through evidence-based learning support approaches by a) scaling up existing Supplemental Instruction (SI) in chemistry and mathematics and b) expanding the existing Learning Assistant (LA) program in physics.

This paper presents preliminary results for two interventions designed by the authors and aligned with the goal of offering motivating introductory experiences to freshman in STEM while creating a sense of community among other STEM students. The interventions are: (1) a one-day multi-disciplinary summer orientation (summer15) to give participants the opportunity to undertake projects that demonstrate the relevance of spatial and computational thinking skills (activity 2a in the previous list) and (2) a follow-on six-week spatial visualization skills training (fall 2015) for students in need to refine these skills. The interventions have spatial skills as a common topic and introduce participants to career applications through laboratory tours and talks. According to the framework proposed by Swail et al.[1], the three elements to address in order to best support students' persistence and achievement are cognitive factors, social factors, and institutional factors. The interventions address all three elements to some extent.

The results in this paper are preliminary as they are based on only the first year of the grant period (2015-2018). For freshman in need to refine their spatial skills, the assessment of spatial visualization skills and the subsequent training is a way to prolong the summer orientation goal of offering motivational introductory experiences while creating community among other STEM students. The training also aligns with the grant ultimate goal of improving STEM retention. For instance, Bairaktarova et al.[2] mention that spatial skills ability is gradually becoming a standard assessment of an individual's likelihood to succeed as an engineer. Metz et al.[3] report that well-developed spatial skills have been shown to lead to success in Engineering and Technology, Computer Science, Chemistry, Computer Aided Design and Mathematics.

The paper is divided in three sections. The first one reports on the summer orientation. The second one reports on the spatial visualization skills training. The sections are subdivided and each of them includes separate literature review, research questions, description of the interventions and results subsections. Conclusions and future directions are in the third section.

Summer orientation

1. Literature review

The literature on the impact of freshmen multi-disciplinary STEM summer orientations is scarce. The work in Callahan et al.[4] parallels to our effort because they looked to design an orientation and a set of correlated activities to increase retention rates for freshman in multiple STEM fields (science, math and engineering). A difference between Callahan et al.[4] work and ours is that their two-day orientation had no particular technical topic and was limited to informing about curriculum requirements and career paths, providing course advising and introducing key human resources. The three correlated activities that Callahan et al.[4] developed to complement the orientation goals were access to a mathematics learning system to prepare students across the summer, freshman learning communities and a fall coursework on improving scientific thought reasoning skills for STEM students not ready for calculus.

The literature on summer orientations targeted to single-disciplines is more abundant. To keep this paper at a reasonable length the authors report on the literature that has the best connection to this research. Thompson and Consi's[5] research resemble our work since they developed three theme focused orientations aligned with the goal of offering motivating experiences to freshman. Their orientations exposed students to the excitement and challenges of engineering through a hands-on project and four other social and technical elements. Thompson and Consi's[5] results are encouraging. A compilation of six to seven years' worth of surveys shows that orientations helped freshman to get a sustained student/mentor interaction, meet upperclassmen and friends who could provide guidance and advice during the academic year, and increase students' interest in their fields. The orientations also increased enrollment in the departments.

The scope in Lam et al.[6] work is wider than the one proposed by the authors in this paper since it targets high school students. However, Lam et al.[6] work parallels to this research because it also designs multiple interventions with the ultimate goal of improving student's retention. The pre-college platform reported in Lam et al.[6] consist of three elements. The first one is a six-week summer residential pre-engineering program for 9th -12th grade high school students. The curriculum includes math, sciences, language arts, technical writing and computer science combined with laboratory demonstrations and practical hands-on experience in engineering design. The second element is year-round career workshops at local manufacturing and research facilities and weekly tutorial sessions facilitated by college students. The third one is a one-week summer program following high school graduation to improve math concepts, introduce students to faculty and upperclassmen and perform academic advising and placement testing among others. Data collected for ten years shows that this platform increased access and retention of under-represented students pursuing STEM careers. A 66% (45 out of 68 participants) majored in a STEM academic area and 94% pursued college education. The retention rate for the summer program from year to year was between 59% and 75%.

Further review of best practices of freshmen STEM orientations at other campuses[7] and literature review on how to attract women to engineering and STEM related fields [8-12] guided in the design of the summer orientation reported in this paper. It was decided that it should include the following elements: (1) a focus on a cutting-edge technical topic[7], (2) a couple of activities to engage students on peer interaction[7], (3) space to make friends, learn, build confidence, and develop critical thinking[4-7], (4) emphasis on hands-on activities[5-9], (5) participation of upperclassmen and faculty/staff[5-7] and (6) dissemination of the societal good of STEM careers to appeal female and minorities interests[9].

Pascarella, Terenzini, and Hibel[13] found that the first few informal interactions between students and faculty appeared to be the most important and that as the frequency of interaction increases, the residual achievement showed a diminishing tendency. They also found that interactions “to discuss intellectual or course related matters” and “to discuss matters related to future career” made the most significant contributions. Pascarella, Terenzini, and Hibel[13] are in agreement with the authors approach for designing an orientation with an intellectual focus as opposed to one dedicated only to academic advising and course selection and social aspects.

2. Research questions

Following is the list of research questions regarding the summer orientation. They are aimed to validate that the orientation motivates students in STEM and contributes to build community among other STEM students. The questions also investigate if the orientation topics related to spatial visualization skills, computational thinking, and critical thinking need improvement.

Q1. Are the orientations effective in engaging the students in their chosen fields?
Q2. For which students are the orientations more helpful? Some of the factors to consider are race/ethnicity, gender, high school GPA, and major.
Q3. Are the orientations effective at creating an environment to make friends and encourage peer interaction?
Q4. Are the orientations effective at creating an environment to learn about science, engineering, and the connections between them?
Q5. Are the orientations helpful at supporting development of students’ confidence regarding their chosen career fields?
Q6. Are certain orientation topics more appealing for students than others?
Q7. Are the orientations effective at supporting students’ development of critical thinking?

3. Description of the pilot summer orientation

The one-day orientation was developed and run in the summer semester of 2015. It ran from 9 am – 5 pm and was offered twice. This orientation was in addition to “Bobcat Preview”, a separate mandatory one-week length freshman orientation that includes academic advising and educational and spirit sessions to acclimate students to the campus. The cutting-edge technical topic selected for the orientation was robotics. The objective of the orientation was to introduce the participants to the robotics topic through hands-on activities that demonstrate the relevance of spatial and computational thinking skills, the relationship between science and engineering and the importance of critical thinking and team work.

The orientation started with a welcome and an entry survey to collect participants' demographic information and attitudes towards STEM. Later, students formed groups of two and worked on assembling and testing the LEGO Mindstorms Robots and their sensors. The time allotted for this activity was 2 hours; three undergraduate students and one faculty facilitated the activity. Students were encouraged to brainstorm strategies to minimize assembly time and achieve precise and high speed robot movement. Most of the participants had no previous experience assembling LEGO robots.

Students shared a networking lunch with faculty and other undergraduate students. During this time, faculty gave information about the different STEM related student societies and demonstrated robotics and other engineering applications using Matlab and Mathematica. After lunch, the group joined a scientific laboratory tour (Robotics Lab or Human Computer Interaction and Eye Tracking lab). Participants did hands-on activities and asked questions assisted by faculty and undergraduate students working in the labs. After the tours, participants worked in pairs learning to program the LEGO robots and performing a competition activity[14]. Each team was given a laptop equipped with LEGO Mindstorms software and Excel. The software allowed the teams to program the robots, collect the data, plot a graph and come up with a hypothesis about the time the robot would require to traverse an arbitrary distance specified by the faculty and/or an undergraduate student leader. The teams who did the most accurate predictions won prizes. After the competition ended time was allotted to reflect on the exercise and the lessons learned.

In the last part of the orientation, students watched some highlights from videos related to robot applications previously collected by the faculty and the undergraduate students planning the orientation. A magazine article[15] related to humans and robots interaction was provided as a reading. Freshman engaged in discussing the practical questions: a) how can robots enhance real world operations such as rescue missions, medicine, manufacturing, and transportation? and b) in regards to various majors and fields, which tasks are best facilitated by robots as compared to people? Participants also reflected on the relevance of the reading. After completing this critical thinking exercise, participants took the exit survey and disassembled the LEGO robots.

4. Demographics

About 363 freshman in *Physics, Computer Science, Engineering, and Engineering Technology* were invited to voluntarily attend the one-day orientation. The final total number of students attending the orientation was 17. Students in *Chemistry and Math* were not invited. This was to maintain a small group size in order to allow close individual attention. Figures 1-3 show the ethnicity, gender and major for participants (17 students) and non-participants (346 students). To keep figures 1-3 easier to read, bars for the percent distribution for the total number of invited students are omitted. These bars coincide with the ones for the non-participants since the number of non-participants and the number of invited students are close.

Figure 1 shows that 48% of the participants were African American, Hispanic or Asian. This percentage agrees very well with the fact that ethnic minorities at Texas State University make up 49% of the student body. Figure 1 also shows that percentages of participation for the groups Hispanic and Other (i.e. Native Hawaiian or Pacific Islander, unknown, and American Indian or Alaskan Native) were lower if compared to the percentage of non-participants in these groups. In future orientations, the authors will increase the publicity and inform the counselors advertising the orientations about the importance of having a fair representation from all ethnic groups.

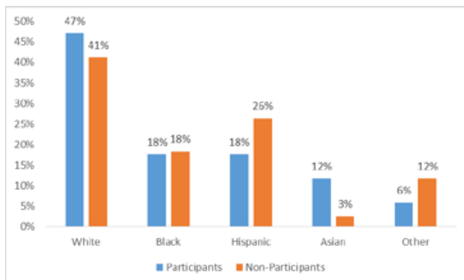

Figure 1: Ethnicity participants and non-participants in the orientation

Figure 2 indicates that the participation of female students in the orientation was 29%. This number is high if compared to the 15% of female students in the non-participants group. The number is also high if compared to the number of female in each of the targeted STEM fields. Available data from the Office of Institutional Research reports the following percentages of female students: 14.8% Computer Science, 13.8% Engineering Technology, 17.15% Engineering, and 13.88% Physics.

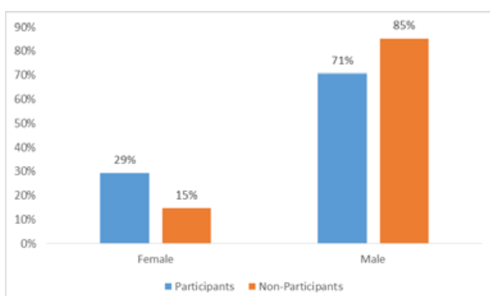

Figure 2: Gender for participants and non-participants in the orientation

Figure 3 reports that 77% of the participants were majoring in Physics or Engineering while only 38% of the non-participants were majoring in these fields. In future orientations, the authors expect to keep a high participation of these majors and at the same time to increase participation of Computer Science and Engineering Technology majors by strengthening the advertisement about the orientations. It is pleasing to learn that the robotics topic seemed to be very appealing to all engineering fields and in particular to Electrical Engineers (EE).

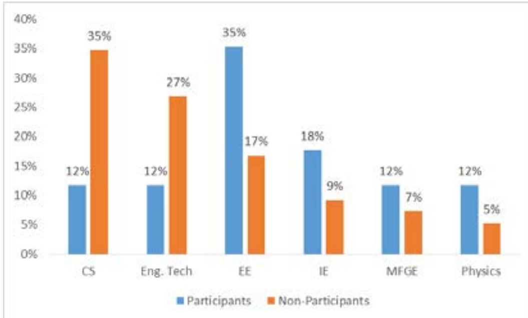

Figure 3: Major for participants and non-participants in the orientation

5. Impact assessment and its correlation to a former summer orientation

The impact of the orientation was assessed by using an exit survey completed by the student participants. The mapping of the five questions (a-e) in the exit survey to some of the research questions listed in Subsection 2 is shown in Table 1. Due to the more complex nature of research questions Q1, Q2 and Q7 they were not asked directly to the participants.

Table 1: Mapping of exit survey completed by participants and research questions

Exit survey question	Exit survey question narrative	Research question
a	Is the orientation effective at creating an environment to make friends and encourage peer interaction? Yes or no and explain	Q3
b	Is the orientation effective to create a space to learn about science and engineering and the relationship between them? Yes or no and explain	Q4
c	What was the most favorite activity of the day? Why?	Q6
d	What was the least favorite activity of the day? Why?	Q6
e	Is this orientation helpful to construct confidence in your chosen field? Yes or no and explain	Q5

The answers for research questions Q3 and Q4 are encouraging; 100% of the participants reported that the orientation was effective in creating a space to make friends and encourage peer interaction. Quotes from students' explanations to this answer included "small group that let interaction", "met people with similar interests", "working in teams allowed collaboration", "fun and interactive" and "made friends". Similarly, 100% of the participants considered that the orientation was effective to create a space to learn about science and engineering and the relationship between them. Their explanations included "we were able to see the relationship between the two by the robot activity", "learned differences and similarities", and "showed us how science is needed in the problem solving process".

The high percentages obtained for Q3 and Q4 also link and in some way surpass the ones in an exit survey one of the authors administered in a former summer orientation (Summer 2013) with a relatively similar format. The orientation was offered to 18 talented, low-income students

(83.33% female, 16.67% male) enrolled in a scholarship program. The former summer orientation did not include Q3 and Q4 but included the question: “Did you gain anything from the orientation?” In the former orientation, 16 out of 18 (88.88%) participants reported that they gain anything from the orientation.

The favorite activity of the 2015 orientation day (i.e. answer to Q6) was assembling the robot (64.3%) and the laboratory tours (28.6% biometrics lab and 7.1% robotics lab). All participants majoring in Computer Science, Engineering Technology, Industrial and Manufacturing Engineering indicated that assembling the robot was their favorite activity while all the Physics majors didn’t choose it as their favorite. For students majoring in Electrical Engineering, opinions about the favorite activity of the day were equally divided between assembling the LEGO and doing the laboratory tours. Besides, assembling the robot was the favorite activity for 58% of the female and 60% of the male participants and no pattern regarding ethnicity was observed in the answers to this question. The students’ reasons for selecting assembling the robot as response were expressed by their comments: “able to work with a partner”, “cool to see other designs”, and “challenging but fun”. The students’ reasons for selecting the lab tours were “very interesting” and “with many future applications”.

Regarding which was the least favorite activity of the day, 35.71% of the participants answered none. The remaining 64.29% answered: “listening to the list of organizations because I like hands-on activities” (7.14%), “disassembling the LEGO robot because it has many tiny parts” (7.14%), “the entry survey because it was a bit too long” (14.29%), “tour to biometrics lab because it took too long ” (7.14%), “walk to the biometrics lab because it’s summer” (7.14%), “assembling robot because is time consuming” (7.14%), “data collection in the competition activity” (7.14%) and “tour to robotics lab because there were no demonstrations with the larger robots” (7.14%). There were no patterns in ethnicity, student major or gender regarding the selection of the least favorite activity of the day.

The former orientation (summer 2013) to the18 students enrolled in a scholarship program took 5 days and consequently included a larger number of activities in which students had to actively participate, individually or as a team. Table 2 shows average and standard deviations for the responses to the question: “How useful did you find the different topics covered in today’s orientation on a scale from 1 (not at all useful) to 5 (very useful)?” Table 2 shows that participants in the 2013 orientation gave the highest scores to: (1) taking the Purdue Spatial Visualization Test (PSVT-R) to learn about their spatial skills and (2) working on the LEGO robots activity. The findings in the former orientation strongly supported the selection of topics for the summer and fall 2015 interventions. Furthermore, it is reassuring to see the correlation between the percentages of satisfaction with the LEGO robots activity reported for the Summer 2013 and the Summer 2015 orientations. In summer 2013, 66.67% of the students voted the LEGO activity as very useful (4-5 score) and in summer 2015, 64.30% of the students voted LEGO as the favorite activity of the day.

Table 1: Average ratings and standard deviations for activities assessed by participants in summer orientation 2013 (1= not at all useful, 5=very useful)

Activity	Average	Standard Deviation
Focus group	3.78	1.11
Purdue spatial visualization skills test (PSVT-R)	4.12	1.05
Assembling LEGO and "going the distance" competition	3.89	1.18
Paper airplane	3.56	1.46
Discussion of readings in engineering/computer science magazines	3.28	1.41

The answers to Q5 were informative since 78.57% of the summer 2015 participants considered the orientation helpful to construct confidence in their chosen field. Quotes from students were "It gave me more info about my major", "I can see what to expect in future courses", "yes, this is my passion", "gave me confidence to interact with peers and opportunity to listen to other explanations", "it showed me the hands-on version of my major and motivated me". The 21.43% that answered "No" explained their answer in the following ways: "didn't talk too much about other fields", "wanted more instruction about electrical engineering" and "showing more on the robots and explanation on how our majors are applicable to robotics would be fun". These comments are helpful to guide future directions discussed in the last section of this paper.

Spatial visualization skills training

1. Literature review

The National Science Board 2010 report[16] recognized that besides math and verbal skills spatial visualization skills (SVS) are necessary for the success in STEM. Strong SVS have been shown to be critical to the success of engineers and students in the fields of Engineering, Technology, Computer Science, Chemistry, Computer Aided Design and Mathematics[3, 17, 18, 19]. The assessment and remediation of those skills is growing in engineering curricula across the country[2, 17, 18, 20, 21]. The 3D spatial skills of female often lag behind those of men[17]. Research and practice have shown that proactive spatial testing of first-year and second-year engineering students plus a follow-on spatial course for those with weak skills contributes to the success of engineering students[17, 21, 22]. Furthermore, in the former summer orientation (summer 2013) offered to 18 talented, low-income students (83.33% female, 16.67% male) one of the authors collected data about the time teams of two students took to assemble the LEGO robot (not including the time to assemble and test the sensors). The average time was 47 minutes, the standard deviation was 16 minutes, the minimum was 25 minutes and the maximum was 72 minutes. These results evidence the need to reduce existing differences in SVS for freshman students attending Texas State University.

Based on the findings cited in the previous paragraph regarding the relevance of strong SVS to multiple STEM fields and motivated by the ultimate project goal of increasing students' retention, the authors decided to complement the one-day summer orientation by designing a follow-on six-week SVS training to students in need to refine these skills.

2. Research questions

The long-term research questions for the SVS training at Texas State University are:

1. Is the Texas State University training effective to improve SVS?
2. Is there any group of students (i.e. female, Hispanics, engineering students, etc.) for which the training is more beneficial?
3. a. Is there any correlation between SVS scores and GPA's?
   b. Is there any correlation between SVS scores and 1st and 2nd year grades in STEM courses?
4. For which STEM courses are the SVS more relevant?
5. In what ways do students change in their understanding of the relevance of SVS to future careers after taking the training?

3. Description of the pilot spatial visualization skills training

The pilot training was developed and run in the Fall 2015 semester. It was recommended for students taking the Purdue Spatial Visualization Test - Rotations (PSVT-R) and scoring below 70% (21 correct questions out of 30). The 70% benchmark was set after analyzing data collected for the 18 scholars in the former summer orientation (summer 2013) and observing a positive correlation between students' PSVT-R results and students' status (continued or dropped).

The training consisted of six sessions (one session per week) and each session lasted two hours. A session started with a twenty minutes talk related to STEM and usually concerning to a practical application of SVS. The speakers were upper-division students, industry representatives, and faculty from different STEM fields. Speakers prepared the talks in a way that facilitated informal interaction and encouraged participants to ask questions. The purpose of the talks was to motivate students to STEM, stress the relevance of SVS and build community. The remaining 1.5 hours of the session were dedicated to lecture, use of a computer program specially designed to develop SVS, and practice using snapcubes and the white board. The training instructor had high experience teaching the subject.

Over 580 freshman in *Computer Science, Chemistry, Bio-chemistry, Math, Applied Math, Physics, Engineering, and Engineering Technology* plus students registered for the Physics-Mechanics and Fundamentals of Architectural Problem and Design courses were invited to take the PSVT-R test on-line through the Texas State University Teaching Research and Collaboration System (TRACS). A total of 115 students took the test and 74 scored below 70%. These students scoring below the benchmark of 70% were invited to sign-in for the training. A total of 7 students voluntarily enrolled in the training and attended it regularly. A special challenge for developing this new training at Texas State University is that the state legislature implemented a law that limits the number of hours that can be required for a college degree. As a result, it is not a current option to add the SVS training to the curricula as a for credit course.

4. Demographics and impact assessment

The participants in the SVS training were 43% female and 57% male. Regarding ethnicity, 57% were Hispanics, 29% White and 14% Asiatic. The majors for the participants were Electrical Engineering 57%, Bio-chemistry 29%, and Manufacturing Engineering 14%. The authors hope to keep the high participation of female and Hispanics in the training and find this result encouraging.

The sample size in this pilot training is too small for extensive statistical analyses. However the pilot findings will impact future programming and research. Indications from the pilot study include: (a) the average improvement in students' scores is statistically significant and equal to 18.334% and (b) all students improved their considerably low pre-training scores (before training average score: 42.78% vs. post-training average score: 61.11 %.) The SVS training will be offered again in the Spring 2016 semester.

The impact of the training was also assessed through an exit survey completed by the student participants. Results indicated that on average students perceive the talks from invited speakers "quite useful". Also, the participants recommend to allocate the same amount of time to invited speakers. All the participants reported that through the training they refined their understanding of the relevance of SVS to future careers.

Conclusions and future directions

This paper presented the methodology guiding the development of a summer orientation and a training to refine spatial visualization skills. These interventions are aimed at improving the motivation of students to STEM and creating a sense of community among STEM students. It has been shown that the agendas for both interventions have been successful in motivating students in their STEM fields.

Due to the early stage of the interventions, the authors cannot conclude about their impact on students' persistence and academic success. It is anticipated that the training may have more impact on students' retention than the orientations. This is not only because the total training length is 12 hours while the orientation is 7-8 hours but also because the training specifically targets a population at high risk of not succeeding in STEM fields. However, an insight from this pilot study is that the orientations are effective to connect students with other activities in the NSF IUSE grant and that such synergy seems like another positive way to impact students' retention. The assessment of the impact on the synergy of the researched interventions with the remaining ones in the grant is a topic for future work.

Through the results collected from the exit surveys on both interventions, this study seems to align with past research[13] that found that the first informal interactions "to discuss intellectual or course related matters" make a significant contribution to freshman attitude towards academic work. The informal setting in which faculty, undergraduate students and freshman interacted has provided also a fun and memorable experience for students.

Additional knowledge acquired from this study is that in the next orientation session, Chemistry and Mathematics majors should be invited. In this way, the capacity of students for each orientation day will be reached. New activities and demonstrations that include more robotics and engineering content are being developed. In the next spatial visualization skills training, faculty teaching first and second year STEM courses will be contacted to broadcast even more the goals and benefits of the training.

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References

1. Swail, W.S., Redd, K.E., & Perna, L.W. (2003). Retaining minority students in higher education: A framework for success. *ASHE-ERIC Higher Education Report, Adrianna J. Kezar, Series Editor*, 30, 2. San Francisco, CA: Jossey-Bass.
2. Bairaktarova, D., Reyes, M., Nassr, N., & Carlton D.T. (2015). "Spatial Skills Development of Engineering Students: Identifying Instructional Tools to Incorporate into Existing Curricula," Proceedings of the 2015 American Society for Engineering Education Annual Conference & Exposition, Seattle, WA, June 14-17, 2015. USA: American Society of Engineering Education.
3. Metz, S., Sorby, S., Reap, J., Berry, T., & Bottomley, L. (2013). "Implementing ENGAGE Strategies to Improve Retention: Focus on Spatial Skills". Spatial Skills Panel, American Society for Engineering Education Annual Conference & Exposition, Atlanta, Georgia, June 24, 2013. USA: Engage - Engaging Students in Engineering. Retrieved from https://static1.squarespace.com/static/5436928ee4b03e07f798150b/t/55159382e4b090722fa990ab/1427477378872/ASEE+SVS+Panel+FINAL+2013+3.27.2015.pdf
4. Callahan, J., Garzolini, J.A., Hunt, G.L., Guarino, J., Bullock, D., Shadle, S., & Schrader, C.B. (2011). "The Idaho science talent expansion program: Improving freshmen retention for STEM majors," Proceedings of the 2011 American Society for Engineering Education Annual Conference, Vancouver, BC, Canada, June 26-29, 2011. USA: American Society of Engineering Education.
5. Thompson, M.K., & Consi, T.R. (2007). Engineering outreach through college pre-orientation programs: MIT discover engineering. *Journal of STEM Education*, 8 (3&4), 75-82.
6. Lam, P.C., Srivatsan, T., Doverspike, D., Vesalo, J., & Mawasha, P.R. (2005). A ten year assessment of the pre-engineering program for under-represented, low-income and/or first-generation college students at the University of Akron. *Journal of STEM Education*, 6, (3&4), 14-20.
7. Compass Project. "The Compass Project - Summer Program." Retrieved from http://www.berkeleycompassproject.org/.
8. Milgram, D. (2007). Gender differences in learning style specific to science, math, engineering and technology (SMET). *National Institute for Women in Trades, Technology & Science*, 1-5. Retrieved from http://www.iwitts.org/component/zoo/item/gender-differences-in-learning-style-specific-to-science-technology-engineering-and-math-stem.

9. Bailey, L. (2004). “Building greenhouses and futures - Introductory engineering class hits on formula to attract women.” November 24, 2004. *University of Michigan – The University RECORD Online*. Retrieved from http://ns.umich.edu/new/releases/5703-introductory-engineering-class-hits-on-formula-to-attract-women.
10. Diefes-Dux, H., Follman, D., Imbrie, P.K., Zawojewski, J., Capobianco, B., & Hjalmarson, M. (2004). “Model eliciting activities: An in-class approach to improving interest and persistence of women in engineering,” Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT, June 20-23, 2004. USA: American Society of Engineering Education.
11. Faulkner, W. (2006). Genders in/of engineering: a research report. Edinburgh: The University of Edinburgh.
12. Felder, R., & Brent, R. (2005). Understanding student differences. *Journal of Engineering Education*, 94(1), 57-72.
13. Pascarella, E.T., Terenzini, P.T., & Hibel, J. (1978). Student-faculty interactional setting and their relationship to predicted academic performance. *The Journal of Higher Education*, 49(5), 450-463.
14. Turfs University Center for Engineering Education and Outreach. (2009). Intro to Robotics in Engineering - Lesson 2. Retrieved from http://sites.tufts.edu/stompactivitydatabase/files/2013/06/Introduction-to-Robotics.pdf
15. Colvin, G. (July 23, 2015). Humans are underrated. *Fortune*, 100-112.
16. National Science Board 2010 report. Retrieved from http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf.
17. Sorby, S.A. (2001). A course in spatial visualization and its impact on the retention of women engineering students. *Journal of Women and Minorities in Science and Engineering*, 7(2), 153-172.
18. Veurink, N.L., Hamlin, A.J. (2015). “Comparison of on-line versus paper spatial testing results,” Proceedings of the 2015 American Society for Engineering Education Annual Conference, Seattle, WA, June 14-17, 2015. USA: American Society of Engineering Education.
19. Humphreys, L.G., Lubinski, D. & Yao, G. (1993). Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. *Journal of Applied Psychology*, 78, 250-261
20. Miller, C.L. & Bertoline, G.R. (1999). Spatial visualization research and theories: Their importance in the development of an engineering and technical design graphics curriculum model. *Engineering Design Graphics Journal*, 55 (3), 5-14
21. Sorby, S.A. (2009). Educational research in developing 3D spatial skills for engineering students. *International Journal of Science Education*, 31(3), 459-480.
22. Engage - Engaging Students in Engineering. “Spatial Visualization Skills (SVS): Learn More.” Retrieved from http://www.engageengineering.org/spatial/whyitworks/learnmore#5