AC 2012-5153: MEASURING THE DIFFERENCES IN SPATIAL ABILITY BETWEEN A FACE-TO-FACE AND A SYNCHRONOUS DISTANCE EDUCATION UNDERGRADUATE ENGINEERING GRAPHICS COURSE

Dr. Wade H. Goodridge, Utah State University

Wade Goodridge, Principal Lecturer in the Department of Engineering and Technology Education at Utah State University, instructs Solid Modeling, CAD, Introductory Electronics, Surveying, and Introductory Engineering courses at the Brigham City Regional campus. Goodridge has has been teaching for the Utah State College of Engineering for more than eight years. He holds dual B.S degrees in industrial technology education and civil engineering from Utah State University, as well as an M.S. and Ph.D. in civil engineering from Utah State University. His research interests include metacognitive processes and strategies involved in engineering design using solid modeling, learning style impacts upon hybrid synchronous broadcast engineering education, and team teaching in broadcast environments.

Dr. Scott David Greenhalgh, University of Northern Iowa

Scott Greenhalgh is an Assistant Professor in the Department of Industrial Technology at the University of Northern Iowa. Greenhalgh's professional interests include collaborations between the STEM fields in teacher preparation. His research interests include cognitive processes in the engineering, technological, and creative design processes.

Dr. Oenardi Lawanto, Utah State University

Oenardi Lawanto is an Assistant Professor of the Department of Engineering Education at Utah State University. Lawanto holds B.S. and M.S. degrees in electrical engineering and a Ph.D. in human resource education. His research interests include areas in cognition, learning, instructions, engineering design, and e-learning. Currently, he is working on two research projects that investigate students' cognitive and metacognitive activities while learning engineering. Both projects are funded by the National Science Foundation (NSF).

Dr. Gary A. Stewardson, Utah State University

Gary Stewardson is an Associate Professor in technology and engineering education at Utah State University. His curriculum and research interests include student learning in the areas of problem solving, engineering design, creative thinking, and spatial ability.

Measured Differences in Spatial Ability between a Face-To-Face and a Synchronous Distance Education Undergraduate Engineering Graphics Course

Abstract

Distance education is growing at colleges and universities throughout the United States. Engineering graphics laboratory courses are unique in their focus on skills and design with an emphasis on a hands-on approach when compared to many subjects which focus on mastering information. Most studies in the literature focus on how distance learning has impacted traditionally lecture based curricular approach and have not focused on classrooms which are traditionally laboratory based as would be typically found in many engineering graphics courses. This study measured and compared spatial ability as it is an essential component to engineering graphics and has a highly correlated measure of success in engineering and other STEM disciplines. The purpose of the study was to measure and compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. The Purdue Spatial Visualization Test of Rotations (PSVT:R) was used to collect the data through a pretest conducted at the start of class and posttest administered at the courses completion.

Results indicate a difference in spatial visualization progress for the two instructional mediums. Students with a low beginning spatial ability showed greater improvement ($p < .011$) in the face-to-face courses ($m = 3.50$, SD = 1.93), than in the synchronous distance education courses ($m = 1.39$, SD = 2.25). As suggested by literature, there were a high proportion of females in this first group, suggesting that female students may be impacted more than male students by a course with synchronous distance education. Further inquiry is suggested regarding how synchronous distance education impacts students with varying spatial ability upon entering courses. Likewise, further inquiry is suggested to look at how various methods of delivery in distance education impact spatial ability in engineering graphics courses.

Introduction and Literature Review

Within the last decade post-secondary education has seen a large growth in the implementation and delivery of curriculum through distance education. It has been found that the number of students taking distance education courses has grown 12 – 17 percent every year since 2004 compared to an annual growth of less than one percent for traditional (face-to-face) courses[1,2]. A meta-analysis of 99 experimental and quasi-experimental studies comparing online courses to equivalent face-to-face courses found that students in distance education courses perform as well as or better than their counterparts on meeting measurable learning objectives[3].

Distinct advantages to distance education exist that facilitate such growth. The ability of the distance education course to reach a greater and more diversified segment of students with limited access to educational opportunities is one such advantage. Another attractive advantage involves finances. Distance education makes it possible to maintain lower costs with regards to overhead and facilities. While many academic courses exist in the distance education environment one particular area of education has been slow to join. Laboratory classes involving hands on laboratory experiences and physical data collection in the fields of science, technology, engineering, and mathematics (STEM) have proven more difficult to implement within the broadcast education medium. Many educators advocate the requirement for an instructor's physical presence as mandatory in these laboratory based environments stating that it is particularly vital to demonstrations and presentations. They argue a physical presence is needed to facilitate clarification, rapid feedback and on site assessment in the laboratory setting. In addition many STEM laboratories have instructors present for safety concerns, maintenance and upkeep of laboratory tools and equipment[4]. These factors and the apprehension of eliminating an instructor's physical presence during class limit the offerings of experiential laboratory courses.

There is an inherent difficulty faced when comparing various engineering graphics courses involving both the lack of standard criteria for evaluating lab activities[4] and the finding of a test instrument meeting the criteria of quality research. Totten and Branoff[5] identified three major challenges in creating an engineering graphics distance education course. The challenges include finding appropriate ways to demonstrate the software, preparing graphically intensive materials, and determining adequate methods to evaluate student work. Despite the lack of a clearly defined standard and objective for engineering graphics courses a generally accepted goal of these courses involves the development or improvement of 3-D spatial visualization[6].

Smith states the essential importance of spatial ability to the field of engineering graphics[7] and Ferguson[8] has pointed out that engineering and technical graphics are described as a means whereby one person can convey mental images to another. To be more precise, the national Council of Teachers of Mathematics[9] in *Principles and Standards for School Mathematics*, defines spatial visualization as: "building and manipulating mental representations of two- and three-dimensional objects and perceiving an object from different perspectives." Similar key terms in the literature associated with spatial visualization include spatial ability, spatial perception, and spatial intelligence. All of these basically refer to an ability to mentally represent and manipulate two and three dimensional objects. The construct of spatial ability can be divided into two main constructs: spatial orientation and spatial visualization. The former simply involves the manipulation of the position of the object and involves no physical changes to its features while the latter involves such physical alteration[10].

Interest in spatial capability has spurred psychologists and educators to develop a number of spatial ability tests. Such tests provide researchers with an effective instrument that can be utilized in assessing whether the absence of the physical presence of the instructor in the classroom has any effect on the outcome of the spatial ability in an engineering graphics course. The most common spatial ability test involves how an individual mentally rotates objects[11]. Two other tests included the ability of an individual to mentally cut or create orthogonal projections of an object[12]. This study conducted a pre- and post-test using the Modified Purdue Spatial Visualization Test: Rotations (PSVT:R) Test, which involves rotating objects. For over thirty years this test has been the most widely utilized spatial visualization test.

Many researchers classify individuals with either high or low spatial ability even though ability is best represented as a normally distributed spectrum rather than a dichotomy. Such a focus is common when the magnitude of the differences between the two extreme groups is so noticeable. Spatial ability is correlated with achievement in many academic fields. Mark Smith[7] has conducted a meta-analysis of many spatial ability correlational studies to academic ability and achievement. Of the twenty-one studies that met the criteria, all studies showed a positive correlation between spatial ability and academic achievement or ability. Gerson et. al.,[13] have also conducted studies involving spatial analysis capabilities correlating participation in a series of special ability tests to an increase in spatial ability.

Gender[14, 15] and hobbies including video games[16, 17] and model construction have been researched regarding consequences upon spacial abilities. Video games were discovered to increase spatial abilities[18] while a major meta-analysis of 286 studies addressing gender differences in spatial abilities indicates a favoring for males with a medium mean effect size of $d = 0.37$. This study looks into some of these factors and will present spatial rotation problems (PSVT:R) with a labeled x, y, and z axes minimizing the bias non-labelled axes impose on results between genders[19].

Research also exists indicating seasonal effects upon student performance[20]. Beşoluk and Önder indicate a higher level of performance in the spring. Similar studies exist researching time of day and day of week impacts upon relative student performance[21, 22]. Results indicate a clear difference in performance between day of the week and time of the day. To as much degree as possible given current class distributions between semester, day, and times, all three factors are worth consideration within a studies design.

Motivation

Distance education courses have provided an advantageous avenue of education for the non-traditional student. Independent research from the Sloan Foundation estimates that there are 4.6 million Americans who took distance education courses in the fall of 2008 [2]. Commitments regarding family and work responsibilities on the non-traditional student often eliminate their ability to attend traditional face-to-face educational experiences. At a time when most institutions are facing large budget cuts, distance education provides an alternative that can be of significant advantage to a university or college provided the outcomes and integrity of the educational process is maintained. Many schools have looked to online courses as a response to budget cuts and rapidly growing student populations[2]. It is imperative that students learning in a distance education model exit the university setting with the same skill sets and knowledge as their peers in a traditional face-to-face setting.

Most work within the literature focuses on the impacts distance education has had upon traditionally lecture based curricular approaches and have not targeted classrooms which are traditionally laboratory based. One specific area of traditional laboratory based instruction lies within the STEM field of engineering graphics. In 2004, fifty-one colleges and universities sampled show that 21% of those schools offered a distance education graphics course[23]. Downs[24] conducted a survey in 2008 of 56 engineering graphics instructors at a variety of colleges and universities showing that 32% offered a distance education engineering graphics course. In contrast to many subjects focusing on mastering information, engineering graphics laboratories are unique in their focus on skills and design with emphasis on a hand on approach.

The minimal safety risk and a relatively minimal required upkeep to equipment involved in an engineering graphics course makes it a viable avenue for research.

This study was needed to identify the impact of the physical presence of an instructor in a face-to-face course versus the lack of physical presence typical to a distance education course. Specifically, the study will target the impact of such a presence upon the spatial ability of students in a graphics education course. Additionally the study looks at non-curricular factors such as age, gender, prior graphics experience, prior virtual software and gaming experience, hobby and leisure activities, and prior solid modeling experience in an effort to determine how they may have impacted any differences in spatial ability. The study is useful in identifying any remedial measures needed to improve the spatial abilities of specific student populations both in a face-to-face and distance educational medium. With approximately 400,000 students enrolled in engineering programs across the United States each year[25] and nearly all of them taking an engineering graphics course, the impacts of this study could be very informative.

Limitations

This study investigates spatial ability within one type of STEM lab (engineering graphics) with one type of distance education (video enhanced synchronous correspondence). The survey of noncircular factors was limited to those observed in the literature to contribute to spatial ability. This study focuses on a cognitive construct defined as an important aspect of the goals of an engineering graphics course. Generalizations from the study may show some limitations due to demographic and program differences that may exist between subjects, instructors, and material of curriculum for this study and those developed in other areas of the country and world. In addition the convenience sample did not have enough female students to provide a statistically viable data set for gender difference conclusions. This is not unexpected with only an average of 11.4% female enrollment in mechanical engineering[26]. To develop a large enough female sample size with this limited enrollment the study would have to sacrifice the internal controls of having the same instructor, teacher's aide, classroom, software, and curriculum. In addition, the study was conducted with a synchronous broadcast curriculum delivery to two sections in the spring and a face to face curriculum delivery method in the fall. Course meeting times were not within the researcher's ability to change to address concerns with seasonal, time of day, and day of week effects. This is also a limitation of the study.

Research Design

This study utilizes a quasi-experimental design from a convenience sample. Four sections of an introductory engineering graphics course at Utah State University were selected for participation. These classes are delivered to a majority of freshman level mechanical and aerospace engineering students. All four sections were delivered by the same instructor to students within the same lab at different times of the day. Each section meets for 1.5 hours twice a week for 15 weeks of instruction during the semester. During the fall the first section of the course met at 2:00 pm and the second section met at 3:30 pm on Tuesdays and Thursdays. During the spring the first section met at 7:30 am and the second met at 12:30 pm with the former meeting on Tuesdays and Thursdays while the latter met on Mondays and Wednesdays of the week. Data was collected during these regular meeting times each semester. Two of the four sections were taught through video conferencing with the instructor located at a remote location while the other two sections were taught with face-to-face instructional methods with the instructor physically present. Students registering for the course at the start of the semester did not know the type of instruction they were registering for. This eliminates self-selection as a threat to the internal validity in the study. All four sections utilized the same teacher's aide who was present on site for all four sections of the study. The teacher's aide graded papers, collected assignments, and answered general questions for students. The instructor has taught this particular course for over two years and the teacher's aide has been present since the beginning. This experience should minimize threats to validity due to maturation effects. The two sections taught with video conferencing were taught during the fall semester of 2010 and the two sections delivered face-to-face where conducted during the spring semester of 2011. The instructor was physically present during the first two classes for the video conference broadcast course to help students understand the broadcast process. The course uses SolidEdge, a three dimensional parametric (virtual) software used for solid modeling design in mechanical applications. The course material focuses on the creation, manipulation, assembling, and modeling of three dimensional virtual objects. Approximately 30 students were enrolled in each section of the course providing a sample size of approximately 60 students in both the face-to-face and synchronous distance education populations.

Instrument Design

Two instruments were used for data collection in the study. The Modified Purdue Spatial Visualization Test of Rotations (PSVT:R) was used to collect data regarding spatial abilities while a demographics survey collected data regarding gender and hobbies for this study. The PSVT:R is a widely used spatial visualization instrument that has been applied for over thirty years. Consisting of 30 analogy test items this test requires the visualization and identification of an object when rotated to a new position. Isometric representations of the object are provided and students select the answer that is appropriate based on their ability to visualize the rotation. This mental rotation of objects fits into the engineering graphics course curriculum and course goals.

The demographic survey focused specifically on the following demographic and non-circular factors: gender, age, major, previous graphics and drafting courses, current and past time spent with construction and mental perception hobbies involving Legos, Connex, and similar toys, and video game use based upon virtual reality. The survey incorporated a combination of pre-categorized demographic questions and four-point likert scale questions. This survey was published and delivered to students online through surveygizmo from Widgix, LLC.

Data

A pre-test and post-test was administered to 122 participating students in the first and last week of the semester, respectively. The test administered was the Modified Purdue Spatial Visualization Test of Rotations with fifteen weeks passing between the pre- and post-tests. Both tests had the same form to avoid issues pertaining to reliability. In addition, both tests had a balanced design between the experimental and control groups to equally distribute the impact effects of testing validity. Students were given 40 minutes to complete the 30 question test.

Non-circular and demographic questions were inclusive to the post-test questions. 65 students were from the face-to-face sample while 57 students were from the distance education sample. Table 1 provides information regarding the range of scores possible, source of data, variable type, and values to be utilized in the analysis of the data.

Demographic Data

Eleven students of the testing group completed the pretest of the PSVT:R but did not complete the post test. Neither pre- nor post-test was mandatory for students. Four students took the post-test of the PSVT:R but did not take the pre-test. The discrepancies are attributed to a variety of factors including tests being administered during the regular class period with some students dropping the course after the first few weeks. Many students add this course after the first week and this explains those students taking the post-test only. In addition there is the issue of absence during the allotted testing time. There were no students known to the instructor or researcher who simply opted out of the study.

Table 1: Collected and Analyzed Study Data

Factors	Sources	Variable Type	Score Ranges
Spatial Ability	PSVT:R	Continuous	0-30
Characterization of Spatial Ability	Pre-test of PSVT:R	Ordinal	Low, Medium, High (1-3)
Gender	Survey	Nominal	Male or Female
Age	Survey	Ordinal	18, 19, 20, 21-22, 23-24, 25 and older
Previous Drafting Experience	Survey	Ordinal	0-6 courses
Experience with Hobbies Subcategories: Building/ assembly, Model construction, Robotics, Radio-controlled toys, Video Games, Programming	Survey	Ordinal	Very little to none, Some, Moderate, Considerable (1-4)
Experience with Extra-curricular activities Subcategories: FIRST Robotics, JETS, Future City, TechXplore, VEX Robotics, Think Quest, Lego Engineering,	Survey	Ordinal	Very little to none, Some, Moderate, Considerable (1-4)

INSPIRE!, Botball,
Odyssey of the Mind

The majority of the students in the study were between 18 and 24 years of age. A higher number of students were above the age of 21 due to the predominant religion in the area asking members to serve two year missions between the ages of 19 and 21. The majority of the study participants were male with only 7 of the full 122 participants being female. With 5.7% of the participants being female the study reflects a lower average than the 11.4% female students nationally recorded as receiving bachelor's degrees in mechanical and aerospace engineering[26]. Only one student in the study reported not majoring in mechanical and aerospace engineering.

Data Analysis

The Purdue Spatial Visualization Test of Rotations (PSVT:R) is the independent variable of the study. Participants in the study took this test in the first week and the last week of the semester. The researchers categorized the students' beginning spatial ability into low, medium, or high categories based on spatial ability from scores on the pre-test given in the first week of the class. Students receiving a score within the lower third of scores were considered to have lower spatial ability, the middle third of scores reflected medium spatial ability, and the higher third reflected high spatial ability. The change in spatial ability was calculated for each participant by subtracting the pre-test score from the post-test score of the PSVT:R. The change in spatial ability was the independent variable for the research questions in the study. The mean change in spatial ability was an improvement of answering 0.88 questions more correctly on the post test compared to the original pre-test. Most students scored relatively high on the 30 question pre-test (mean = 26.06, median = 27), plateauing scores with little room for improvement for many students.

The factor of student's beginning spatial ability is a predictive variable for this study and was created by rank ordering pre-test scores and dividing students into group sizes as equitably as possible. This division was implemented to see if instructional strategies had an impact on students by sub-groups of beginning spatial ability. Table 2 shows how the groups were subdivided. Using a Least Significant Difference (LSD) post-hoc test upon an analysis of variance (ANOVA) test, the research found a significant ($p = 0.001$) difference in the change in spatial ability according to beginning spatial ability for low, medium, and high spatial ability groups.

Two measurements of student demographics were tested for correlation to the independent variable of change in spatial ability. Using a Pearson Correlation between age and change in spatial ability ($p = .475$) and between age and pre-test score of spatial ability ($p = .212$) no significant correlations were found. Even with the very few female study participants there was a significant difference in an independent samples t-test ($p = .002$) in the mean scores of female and male students on the pretest. Even with a statistically significant difference between male and female students on the pre-test of the PSVT:R the few number of female participants prevent any definitive conclusions from being drawn. Differences are reported in table 3.

A majority of students had at least one prior graphics or drafting course. It is expected that such experience would correlate to a higher beginning spatial ability. A significant difference in

Table 2: Spatial Ability Group and Statistics for Change In Spatial Ability

Spatial Ability Groups	N	Pre-test Score Ranges	Mean Change in Spatial Ability	SD	SEM
Low	34	16 - 25	2.38*	2.336	.401
Middle	37	26-27	.86*	1.751	.288
High	49	28-30	-.55*	1.415	.202

** denotes statistical significance between groups at p =.001.*

Table 3: Gender Spatial Ability Differences in Pre-Test

Gender	N	Mean of Pre-test Scores	SD	SEM
Female	7	22.29*	3.817	1.443
Male	115	26.30*	3.206	.299

** denotes statistical significance between groups at p =.002.*

beginning spatial ability was found in an independent samples t-test when students had such courses. This is reported in table 4.

Literature has identified hobbies as being correlated with spatial ability. In this study students were asked how much prior experience they have with a variety of hobbies including experience with model construction, programming, remote control toys (RC), video games, and extracurricular involvement. Answers included a selection of *very little to none*, *some*-I play (or have played) around with it a little, but average less than a few hours a month, *moderate*-I play (or have played) with it for several hours a month on average, or *considerable*-I play (or have played) with it for several hours a week on average. The difference in means of beginning spatial ability and the change in spatial ability as a result to the declared hobby can be seen in the table 5 along with the reported experience students claimed.

Results

The comparison of face-to-face and distance education methods was key to this study. Table 6 has the descriptive statistics comparing the two methods. The difference in change in spatial ability was marginally non-significant at p = .078 on an independent sample t-test when comparing the two methods against each other.

There was a statistically non-significant (p = 0.078) difference found when comparing the means of the distance education course to the face-to-face course with a mean difference of 0.70.

Table 4: Previous Graphics or Drafting Course Differences in Pre-Test

Prior Drafting/Graphics Courses	N	Mean of Pre-test Scores	SD	SEM
1 or > Prior Drafting/ Graphics Course	46	26.30*	2.980	.439
No Prior Courses	58	24.72*	3.835	.767

* denotes statistical significance between groups at p =.038.

Table 5: Mean Differences as per hobby in beginning and change in spatial abilities

		ANOVA difference in means (p) between listed hobby and	
Hobbies	Prior Experience	Beginning Spatial Ability	Change in spatial ability
Model Construction	Moderate	0.822	0.216
Programming	Very little/none	0.277	0.467
RC Toys	Moderate	0.277	0.467
Video Games*	Moderate	0.992	0.691
Video Games[#]	Moderate	0.687	0.794
Extra Curricular Inv.	Very little/none	0.592	0.317

* *first person shooter video games*
[#] *flight simulators or driving video games*

Although this statistic was non-significant, the difference in means shows a medium effect size (d =.32). A post-hoc power analysis of the study shows the calculated power to be 0.95. With the effect size being as great as it was, and the p-value being marginally non-significant, this suggests further exploration will be needed to determine if there is no significant difference between the synchronous distance education course and the face-to-face course. If we factor the initial spatial ability of students into the comparison between the change in spatial ability for synchronous distance education delivery and face-to-face delivery we can add another level of analysis for comparison. The mean change in spatial analysis for the synchronous distance education sections compared to the face-to-face sections reflects very little difference in students of medium and high beginning spatial ability, but a significant difference is found in the change in spatial ability for those with a low beginning spatial ability. The mean change in spatial ability for the two different educational approaches factoring in the beginning spatial ability can be seen in table 7.

Discussions

Students with low beginning spatial ability show the greatest improvement in spatial ability when instructed using face-to-face teaching methods as compared to synchronous distance education methods. With the limited female population in this study no definitive conclusions can be drawn, however, the limited data is consistent with literature suggesting a stronger difference in change in spatial ability between female students than male students in a synchronous distance education engineering graphics course compared to the same face-to-face

Table 6: Instructional Method and Change in Spatial Ability Mean Differences

Instructional Methods	N	Mean Change in Spatial Ability	SD	SEM
Synchronous Distance Education	63	0.33	1.82	.233
Face-to-Face	56	1.14	2.40	.320

Table 7: Mean Differences for the Change in Spatial Ability by Beginning Spatial Ability

Beginning Spatial Ability	Instructional Methods	N	Mean	SD	SEM
Low	Synchronous Distance Education	17(1)	1.39*	2.25	0.41
	Face-to-Face	12(4)	3.50*	1.93	0.44
Medium	Synchronous Distance Education	16(1)	0.88	1.87	0.42
	Face-to-Face	19(1)	0.85	1.69	0.39
High	Synchronous Distance Education	29	-0.52	1.24	0.33
	Face-to-Face	20	-0.60	1.67	0.39
Mean		120	0.72	2.17	0.23

** Significant at p = .011 in a Tests of Between Subject Effects for the General Linear Model Measuring Mean Differences in Change in Spatial Ability by Beginning Spatial Ability*
( ) number in parenthesis indicates the number of female students within the group while no parenthesis indicates entirely mail contingent of students

course. The researchers recommend more exploration into this possibility. In addition, the Purdue Spatial Visualization Test of Rotations (PSVT:R) exhibits a possible ceiling effect and may not have allowed the researchers the ability to accurately measure the change in spatial ability for students with higher scores on the pre-test. In effect the students may have improved their spatial ability but could not effectively demonstrate it through answering the questions on the PSVT:R. This could in part be due to a higher level of beginning student spatial ability for current generations as compared to previous generations when the PSVT:R was developed. A future study involving current generational spatial ability as well as historical generational spatial ability is warranted.

The purpose of this study was to focus on the impacts of two separate curriculum delivery models on student's ability to improve spatial ability in an engineering graphics course. In analyzing the delivery method independently with a paired sample t-test against a null hypothesis that there is no change in spatial ability of students over the period of the course, the face-to-face instructional method rejected the null-hypothesis while the synchronous distance education method failed to reject the null hypothesis. Data statistically showed that the face-to-face course had a medium to large effect size (d = .48) on the change in spatial ability over the duration of the course. Similarly, data indicates that the synchronous distance education course had a non-significant small effect size (d = .18) on the change in spatial ability over the duration of the course. There was a statistically non-significant difference ($p = 0.078$) in the mean difference (0.70) of the two different instructional delivery methods. Although this statistic was non-significant, the difference in the means shows a medium effect size (d = .32). With the same effect size and variation in data, a sample size of 245 subjects is recommended to yield enough power ($1 - \beta = 0.80$) to the study to prevent a type II error.

The most notable measurement for comparing the impacts of instructional formats on student spatial ability requires the consideration of the beginning spatial ability of the students. The mean change in spatial ability for students whose beginning spatial ability was medium and high revealed little difference (0.03 and 0.08, respectively) between both educational delivery methods. The mean change in spatial ability for students with low beginning spatial ability is significant (2.11) between students in synchronous distance education sections and face-to-face sections. Statistics associated with this test can be seen in table 7 giving insights into any differences in the change in the spatial ability of engineering graphics students between the synchronous distance education and face-to-face instructional methods.

Findings indicate that students with low beginning spatial abilities improve their spatial capabilities at a greater rate and for a larger total change in a face-to-face class as opposed to a synchronous broadcast delivery class. Many of the factors which have previously provided explanation for variations between distance education and face-to-face hands on courses were held constant in this study. This study used the same instructor and curriculum for all four class sections. Students in all sections were in the same classroom, used the same computers and software, and all had the same teacher's aide. The distance education course was taught synchronously, so delays in feedback for an asynchronous course were not an issue. For this study it is reasonable to conclude that the outstanding factor was the physical presence of the teacher. As a result a question arises as to why the instructor's physical presence has spatial ability impacts. A feeling of student alienation[27] or the difficulty in establishing the interpersonal element of building understanding between instructor and student[28] can possibly account for the trends observed.

In this study 71.4% of the female students were in the lower third of the beginning spatial ability category. Realizing that the sample size in this study is too small to draw definitive conclusions regarding beginning spatial ability of female students to male students, the researchers do point out that the results follow the literature[14]. With the high percentage of female students in this lower beginning spatial ability group the researchers are interested in looking deeper into whether decisions in instructional methods in an engineering graphics course could have a greater impact on female students who are disproportionately represented in the low beginning spatial ability group. Such an inference is of particular importance concerning the improvement of engineering programs and all fields of engineering regarding recruitment and retention of female students[29].

With regards to the non-curricular factors investigated, an extremely weak correlation was discovered. The survey showed that very few students had experience in engineering related extra-curricular activities. 59% of participants had no experience with engineering related activities in this realm. Experience with robotics was the only hobby seen with any correlation to beginning spatial ability. Unfortunately the correlation was in an unexpected direction[30, 31], with the more exposure to robotics correlating to a lower predicted beginning spatial ability. Davis[32] points out the complex nature for the way factors correlate which provides insight into an explanation for this inversely expected correlation. With several aspects, including duration of time spent on hobby, length of time since recent activity within the hobby, age of participant, and the particular facets of the hobby that were of interest, a more detailed mixed methods approach of research focusing on individual hobby aspects is recommended to investigate the hobby correlations to spatial ability. After partialling out the effects of hobbies and extra-curricular activities, a low correlation of hobbies and extra-curricular activities to change in spatial ability was observed. This provided few strong enough factors for partial correlation to show what the effects of instructional delivery methods were.

Recommendations for future work

There was a mean difference in correctly answered questions on the PSVT:R in favor of students who had previously taken a drafting or engineering graphics course. The beginning spatial ability of students was the strongest predictor of change in spatial ability in this study. Students with low beginning spatial ability demonstrated the most gain or change in spatial ability between the pre- and post-test. There was no statistically significant effect shown when the change in spatial ability was analyzed for an interactive effect between having previously taken a graphics course and the beginning spatial ability of the students ($f = .135$; $p = 0.87$) in a general linear model.

Results can be seen in table 8 suggesting that regardless of taking a previous drafting or engineering graphics course students should be able to continue to improve their spatial abilities at the same rate as comparable beginning spatial ability students. The study was not designed to investigate the effects of a previous engineering graphics and drafting courses on the development of spatial ability of students currently taking such a course, but data suggests that a current engineer graphics student’s development of spatial ability is not dependent upon previous graphics experience.

A higher spatial ability has been correlated to success in many STEM fields outside of mechanical engineering. Many such fields require a graphics or drafting course. This study found that a face-to-face course was at greatest advantage for students of low beginning spatial ability. It is recommended that the study be continued for students in the industrial technology,

Table 8: Between Subject Effects Tests for the General Linear Model Measuring Mean Differences in Change in Spatial Ability by Beginning Spatial Ability and Prior Graphics Courses

Sources	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	113.264	11	10.297	2.927	.004
Intercept	26.316	1	26.316	7.482	.008
Beginning Spatial Ability	31.494	2	15.747	4.477	.016
Prior Graphics Courses	6.176	3	2.059	.585	.627
Beginning Spatial Ability * Prior Graphics Courses	13.930	6	2.322	.660	.682
Error	204.007	58	3.517		
Total	367.000	70			
Corrected Total	560.367	119			

R Squared = .357 (Adjusted R Squared = .235)

interior design, landscape architecture, and architecture fields as well as other engineering disciplines. Interior design would prove interesting for its wealth of female student enrollment allowing a deeper look into the impacts of face-to-face and distance education and consequences on spatial ability on the female gender. Such results would be decisive information in administrative decisions on how to offer courses while fostering recruitment and retention of female students.

It is also recommended that this study be applied again with the use of a separate test of spatial ability. The mental cutting test could be another spatial ability evaluator allowing the measurement of an additional factor of spatial ability. This test may also have more room for improvement for students with higher initial spatial skills.

This study targeted the effects of an instructor's physical presence upon student spatial ability for two curriculum delivery methods. Curriculum, physical settings for the student, teacher's aide, and software were identical between the face-to-face and synchronous broadcast course. There are many other forms of distance education including hybrid and asynchronous curriculum delivery that also warrant an investigation into their ability to compare with a traditional face-to-face lecture format.

For both high and medium beginning spatial ability students there is no significant difference in the change in spatial ability between face-to-face and synchronous broadcast education. It is recommended however that students exhibiting a lower beginning spatial ability be given face-to-face instruction. As spatial ability has been correlated to success in many STEM fields, curriculum developers and educators should account for a student's beginning spatial ability prior to placing them in a broadcast education environment.

This study was limited to the delivery times and semesters noted above. For future research the author believes that that the two sections in each semester should target nearly the same time of day and day of week. In addition, one section should be through a broadcast delivery model while the other is face to face. Physical and administrative factors did not allow this study to accommodate any seasonal, time of day, and day of week effects. A future work within this area accommodating these factors would be very decisive in supporting this studies research.

Summary

A larger difference is observable in the change in spatial abilities for students with low initial spatial abilities in a face-to-face traditional engineering graphics course (m = 3.50, SD = 1.93) as compared to a synchronous distance education course (m = 1.39, SD = 2.25). No significant difference in this change in spatial ability could be discerned for students with medium and high beginning spatial ability between both educational delivery models without a larger study group. There were a higher proportion of female students in this lower beginning spatial ability group, as expected from the literature, which suggests that female students may be impacted more by a synchronous distance delivery model than their male counterparts. Further research into distance education impacts on spatial ability in other engineering, technology, and architectural fields is warranted as well as research into different distance education delivery methods and their associated impacts on the spatial ability of students.

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