Spatial Acuity in Engineering Design Graphics[1]

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Virtual modeling allows for higher-order processes, often times involving multiple models and scales to be represented in a clear and pointed manner (Schuchardt, Black, Chase, Elsethagen, & Sun, 2007). There are multitudes of motivational processes that are responsive to individual properties associated with tasks, the classroom, or the context within student engagement (Wolters & Pintrich, 1998). Control, competence, and self-regulated strategic learning remain chief among identified beliefs and constructs in student motivation literature (Shell & Husman, 2008). Awareness of these student belief systems and how they can potentially promote student abilities is of importance concerning task sequencing and the structure of materials/resources in engineering design graphics courses. Previous motivation and learning research indicates that self-efficacy and learning performance are identified as continuing motivational and learning factors for engineering graphics (Clark & Ernst 2008). Additionally, there is an identifiable progression in spatial acuity when students are enrolled in visualization-associated curricula (Clark & Ernst, 2008). Based on findings from these studies, the Purdue Spatial Visualization Test - Visualization of Rotations: Mental Rotation Test and the Motivated Strategies for Learning Questionnaire (MSLQ) Attitude Survey were paired and administered to primarily university undergraduate technology education and engineering students. The intent of this study was to assess the abilities of students to visualize rotated three-dimensional objects and determine associations/relationships with intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy learning performance, and test anxiety. Understanding of student abilities and learning processes, at all levels of attainment, is of high impact concerning instructional design, content sequencing, and strategies for learning.

1. INTRODUCTION

Engineering design and technical graphic researchers have recurrently studied the relationship between virtual modeling and the engineering design process. Clear identification of what is taught in efforts to place value, tools and approaches that are currently and have historically been utilized to impart knowledge, and facilitation of visual skill development for professional readiness are central foci in engineering design graphics. However, little attention has been lent to learner receptiveness and significance concerning technical graphics content. There has been even less focus related to learner motivation, content and appreciation, and specific skill-based outcomes (with the exception of direct modeling application) in engineering graphics courses. One specific skill with large-scale recurring measures in engineering graphics, primarily through the use of the Purdue Spatial Visualization Test -- Visualization of Rotations: Mental Rotation Test, is visual abilities concerning object rotation. Through previous study (Clark & Ernst, 2008), there is suggestive evidence that attainment of visual-based abilities could have an identifiable association with motivation of students in graphics courses.

2. RESEARCH QUESTION

There was a single overarching research question that guided this preliminary study:

RQ1: Are there identifiable differences or associations between introductory engineering graphics students' mental rotation abilities and students' motivational beliefs/use of learning strategies?

There was also a single investigational hypothesis to partially assist in the evaluation of the study research question:

H1:There is no significant difference in means of the student participants' mental rotation abilities and motivation and learning strategy in an introductory engineering graphics course.

To evaluate the hypothesis, a paired samples *t*-test was used to determine if differences existed between the means of the assessment and rating. In efforts to determine association, an additional correlation evaluative measure was employed.

3. INSTRUMENTATION

There were two instruments employed in this study: 1) the Purdue Spatial Visualization Test - Visualization of Rotations, and 2) the Motivated Strategies for Learning Questionnaire. Spatial visualization involves mentally rotating, twisting, or inverting a perceived object (Branoff, 1998). Research has shown that the Purdue Spatial Visualization Test - Visualization of Rotations measures spatial visualization ability (Branoff, 1998). The Purdue Spatial Visualization Test - Visualization of Rotations is one assessment of the numerous Purdue Spatial Visualization Test measurement instruments. The rotations test assesses the abilities of students to visualize rotated 3-dimensional objects. The test consists of 30 questions that

[1] This is a peer-reviewed paper.

call for students to employ their spatial abilities requiring students to study how a given object is rotated, visualize what a second object would look like when rotated in exactly the same manner as the previous object, and select the rotated object that depicts the second object rotated in the correct position from among five rotated object answer choices (Bodner & Guay, 1997).

The second instrument examined motivation. This instrument, known as the Motivated Strategies for Learning Questionnaire (MSLQ), was designed to evaluate college students' motivational orientation and use of varied learning strategies in college level courses (Pintrich, Smith, Garcia, & McKeachie, 1993). The MSLQ is comprised of two sections, one for motivation and one for learning strategies. The motivation segment has 31 items that evaluate students' goals and value beliefs, students' beliefs about skills necessary to succeed, and test anxiety associated with a specific course (Duncan & McKeachie, 2005). Duncan & McKeachie differentiate the learning strategy section as identifying students' use of different cognitive and metacognitive strategies as well as management of resources. The motivation section and the learning strategies section of the MSLQ include 81 items. Each item is rated using a 7-point Likert-type scale. The rating scale ranges from one (not at all true of me) to seven (very true of me). For the purposes of this study, the MSLQ scale was normalized to correspond with the 30 component Purdue and functioned as an overall non-categorical measure of motivation and learning strategy.

4. METHODOLOGY

Participation was requested of students in an undergraduate introductory engineering graphics course enrolled during the second summer session of 2011. Second summer session courses met five times a week for five weeks from the third week in June to the last week of July. Four weeks of instruction proceeded as scheduled with content and associated application including orthographic projection, isometric drawing, sectioning and auxiliary creation, and a complete focus on three-dimensional static model development in a virtual environment. At the completion of the fourth week of instruction, the course instructor administered the MSLQ instrument. The Purdue Spatial Visualization: Visualization of Rotation instrument was administered to the students the following class meeting in efforts to prevent participant fatigue. The course instructor collected the completed instruments, data were entered, and subsequent analyses were conducted based on scale normalization.

5. DATA AND FINDINGS

The introductory engineering graphics students' spatial acuity and motivation and strategies for learning were investigated to find identifiable differences and/or associations. A scatter plot (Figure 1) of Purdue outcome scores and MSLQ cumulative ratings were constructed to provide a visual representation of the array of student achievement for the 37 student participants.

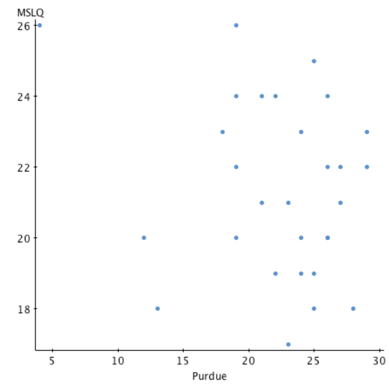

Figure 1. Scatter Plot of MSLQ and Purdue Outcomes

Summary statistics (Table 1) of the Purdue and MSLQ were calculated to provide a synopsis of the instrument results. The variance (6.03) and standard deviation (2.46) of the MSLQ results are minimal in comparison to the variance (29.3) and standard deviation (5.41) of the Purdue results indicating a smaller spread of participant ratings on the MSLQ. The standard error (0.45) of the MSLQ results is smaller than the standard error (0.89) of the Purdue results uncovering a larger fluctuation in ratings from participant to participant in the Purdue results. The range is calculated based on the minimum and maximum scores on the MSLQ and Purdue results. The sizable range (26) of the Purdue in relation to the MSLQ range (9) reiterates the degree of difference in variability of the two instruments.

Table 1. *Summary Statistics*

Column	n	Mean	Variance	Std. Dev.	Std. Err.	Median	Range
Purdue	37	22.60	29.30	5.41	0.89	24	26
MSLQ	30	21.37	6.03	2.46	0.45	21	9

Figure 2 and Figure 3 represent the rate of occurrence for Purdue outcome scores and MSLQ ratings for the introductory engineering graphics students. Both histograms are skewed to the left indicating an upper limit, in this case a maximum score of 100. A histogram representing a distribution is skewed if one of its tails is extended for the lowest or highest values. This non-symmetric distribution is positively skewed if the histogram has a distinguishable tail in the positive direction and negatively skewed in the negative direction (Agresti & Finlay, 1997).

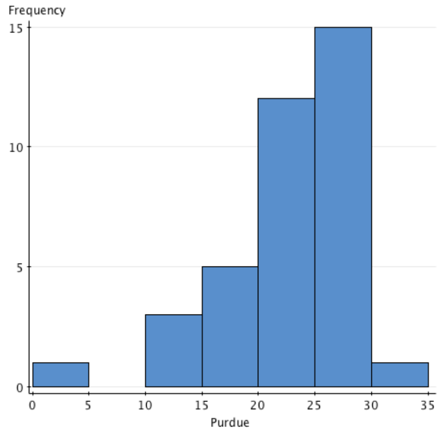

Figure 2. Histogram for Purdue

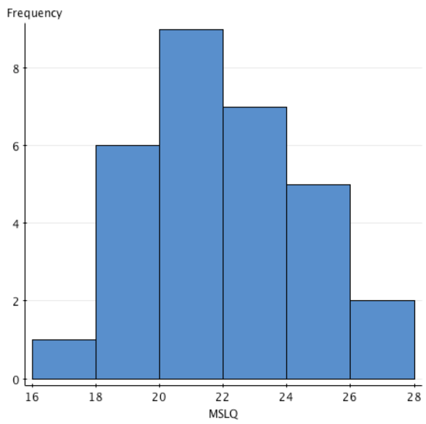

Figure 3. Histogram for MSLQ

Based on the analysis of the T-statistic (0.88) and the proportional value (0.39), the investigational hypothesis failed to be rejected, providing evidence that there is no significant difference in the means of the student participants' mental rotation abilities and motivation and learning strategy in an introductory engineering graphics course.

Table 2. *Hypothesis Test Results*

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
Purdue - MSLQ	1.03	1.18	29	0.88	0.39

Supplementally, a correlation coefficient was calculated (Table 3) between the Purdue outcome scores and the normalized motivation and strategies for learning ratings to determine the strength in association between mental rotation ability and motivation and learning in an introductory graphics course. Based on the results (0.23) shown in Table 3, there is evidence that the two assessment scores do not increase or decrease together, identifying a weak positive correlation.

Table 3. *Correlation Coefficient Purdue and MSLQ*

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
Purdue - MSLQ	1.03	1.18	29	0.88	0.39

6. CONCLUSIONS AND DISCUSSION

This preliminary investigation initiated the identification process of determining if student mental rotation abilities, or visual capability, possesses associative means concerning motivation and learning strategies used in engineering design graphics related courses. Through the use of two standardized instruments, the Purdue Spatial Visualization Test - Visualization of Rotations: Mental Rotation Test to indicate student visual capabilities, and the Motivated Strategies for Learning Questionnaire (MSLQ) Attitude Survey about motivation in a graphics course, the researchers explored the research question: Are there identifiable differences or associations between introductory engineering graphics students' mental rotation abilities and students' motivational beliefs/use of learning strategies?

Upon analysis of the results, no significant difference exists between the mental rotations abilities of students and what motivates them to learn. A very weak positive correlation between mental rotation abilities and motivation does exist between the two instruments' assessment scores, identifying a further need for subgroup analysis. Of specific interest to the researchers pertaining to subgroup analysis is exploring at-risk population differentiation between assessments. Overall, this preliminary study serves as a basis for future studies with a larger population and the ability to perform subgroup analysis based on multiple factors to determine if there are variable associations and at what level. Expansion of these types of studies enhances researcher and practitioner understandings of how students acquire visual skills and how motivation in engineering design graphics courses influences processes and approaches of students. This categorization of study will persist in efforts to concisely provide meaningful learning experiences based on informed study as opposed to on a notion.

7. REFERENCES

Agresti, A., and Finlay, B. (1997). *Statistical methods for the social sciences* (3rd ed.). Upper Saddle River: Prentice Hall, Inc.

Bodner, G.M. & Guay, R.B. (1997). The Purdue Visualization of Rotations Test. *The Chemical Educator*, 2(4), 1-17.

Branoff, T. (1998). The effects of adding coordinate axes to a mental rotations task in measuring spatial visualization ability in introductory undergraduate technical graphics courses. *Engineering Design Graphics Journal*, *62*(2), 16-34.

Clark, A.C. & Ernst, J.V. (2008). Visual science and STEM-based 6-12 education. *Published Proceedings of the American Society for Engineering Education Annual Conference and Exposition*, Pittsburgh, PA, Session 2008-419

Duncan, T.G. & McKeachie, W.J. (2005). The making of the Motivated Strategies for Learning Questionnaire. *Educational Psychologist. 40*(2), 117-128.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement, 53,* 801-813.

Schuchardt, K.L., Black, G.D., Chase, J.M., Elsethagen, T.O., & Sun, L. (2007). Process integration, data management, and visualization framework for subsurface sciences. *Journal of Physics: Conference Series, 78*(12064), 1-5.

Shell, J. & Husman, D.F. (2008). Beliefs and perceptions about the future: A measurement of future time perspective. *Learning and Individual Differences. 18,* 166-175.

Wolters, C.A. & Pintrich, P.R. (1999). Contextual differences in student motivation and self-regulated learning in mathematics, English, and social studies classrooms. *Instructional Science, 26*, 27-47.