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The relationship between persistence, effort, and achievement in a spatial skills training program

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Abstract

The importance of strong spatial visualization skills (SVS) in engineering is well established. Since SVS are rarely specifically taught in the K-12 curriculum, many first-year engineering programs have implemented a spatial skills training program aimed at identifying first-year engineering students with low SVS and giving them the opportunity to gain these critical skills through focused practice. A variety of different implementations of these spatial skills training programs have proven effective in improving spatial ability, ranging from a total training time of 8 hours to over 20 hours.

This objective of this study was to determine whether different amounts of training should be prescribed for students based on initial spatial ability, as measured by the Purdue Spatial Visualization Test of Rotations (PSVT:R). Another objective was to determine the minimum level of persistence required during the training to effectively improve spatial visualization skills (SVS). Training amount is measured by the number of problems completed in the Spatial Vis software by eGrove Education, and persistence level is measured by the average stars per problem.

Participants are divided into three groups based on initial test score: novices (test score below 60%), intermediates (test score between 60% and 69%) and masters (test score 70% and above). A correlational analysis between training persistence and gains in spatial ability was performed for each group. A weak positive correlation was found for the novice group only. A correlational analysis between training amount and gains in spatial ability was also performed for each group. Strangely, a weak negative correlation was found for the novice group. These results indicate a need to more closely examine the effects of persistence and training amount in smaller, more similar subgroups or more carefully consider how to quantify improvement in spatial ability.

Introduction

The ability to mentally visualize and manipulate 3D objects is critical to success in an engineering degree program [1-4]. Students with low spatial visualization skills (SVS) are more likely to leave engineering. Since women and underrepresented groups are disproportionately affected by low SVS, providing students with the opportunity to train and practice their spatial skills is vital to maintaining diversity in engineering [4-7].

The Purdue Spatial Visualization Test of Rotations (PSVT:R) is a standardized test commonly used to assess spatial ability [8]. A score of 70% or higher is considered passing. Students who score below 70% are identified as having low SVS and at-risk for leaving the engineering program. These students are usually encouraged or required to participate in a spatial skills training program to improve their spatial ability before retaking the PSVT:R upon completion of the program [9-11].

Implementation of an effective spatial skills training program can be challenging to fit into an already packed engineering curriculum, without overburdening instructors and students. Since most spatial skill-building activities rely heavily on hand sketching, these programs can require significant time and effort for grading of these activities. The use of a sketching software, such as Spatial Vis by eGrove Education, can provide automatic grading and other advantages [12]. The Spatial Vis software consists of over 300 sketching exercises, separated into 9 lessons that focus on various spatial tasks. Spatial Vis provides immediate and personalized feedback to the student. In addition, the software utilizes a star reward system that increases engagement through gamification and encourages persistence, which is essential to developing spatial skills [13,14].

In the Spatial Vis software, persistence is rewarded by allowing an unlimited number of attempts on a problem. Students who get the problem correct without help (i.e. without a "hint" or "peek") will receive the maximum number of stars, i.e. 3 stars. If they use a "hint", they receive 2 stars. If they take a "peek" at the solution, they receive only 1 star.

Examples of the sketching exercises in the Spatial Vis software are shown in Figure 1, including the automated feedback provided when a "hint" is used.

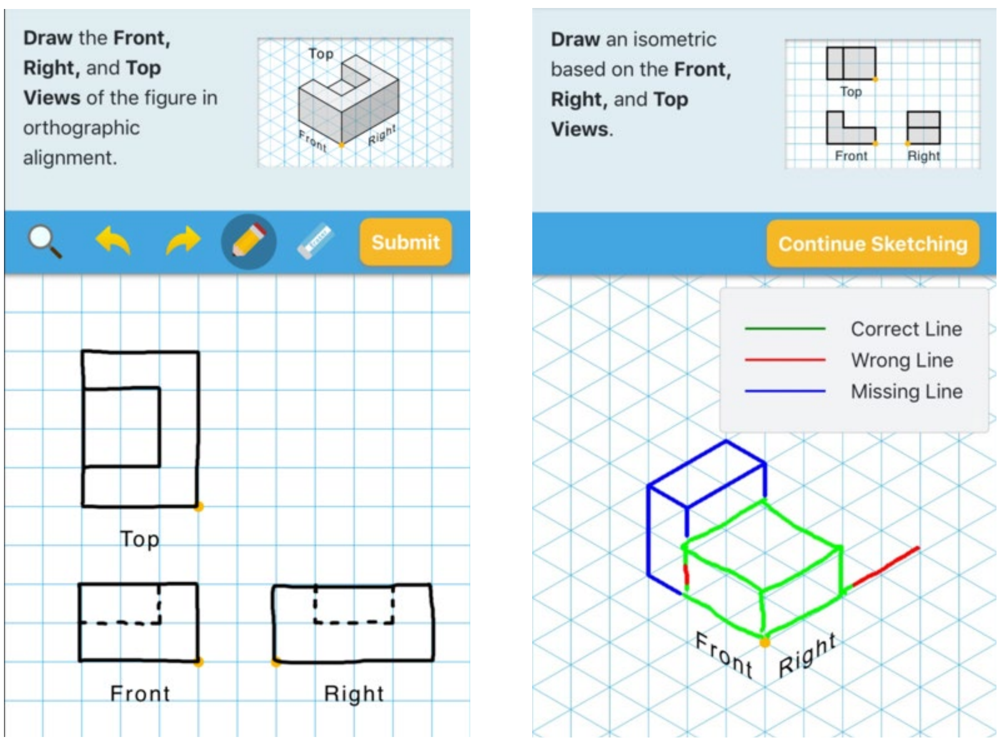

Figure 1. Two example sketching exercises in from the Spatial Vis software: correct sketch of orthographic views (left), and incorrect sketch of isometric view with automated feedback shown upon using a "hint" (right).

While significant gains in SVS have been demonstrated across a variety of different spatial skills training programs [9-11], it remains unclear whether some students require a larger set of training exercises to achieve these gains. The level of persistence required to achieve these gains is also not well defined.

This paper aims to determine whether a correlation exists between improvement of spatial ability and training effort, as measured by the total number of exercises completed. Correlation between spatial ability improvement and persistence, as measured by the overall average stars per exercise, is also investigated.

Methods

An introductory design course is required for all first-year engineering students at Stevens Institute of Technology. This course incorporates elements of design, engineering graphics, and spatial visualization. Students took the PSVT:R in the second week of class and were placed into one of three levels based on their test score, as shown in Table 1.

Table 1. Incentive structure for the spatial visualization component of the course.

Spatial Novice (1 pt)	**Spatial Intermediate** (3 pts)	**Spatial Master** (5 pts)
Test score below 60%	Test score of 60% to 69%	Test score 70% or above

The spatial visualization component counted as 5% of the course grade. Spatial masters earned all 5 pts of the SVS grade, while spatial intermediates initially earned 3 out of 5 pts, and spatial novices initially earned 1 out of 5 pts. All students were assigned a total of 57 problems (approx. 2.5 hours) in the Spatial Vis software over a period of 6 weeks to practice and improve their spatial visualization skills. To encourage persistence, students were asked to complete all assigned problems without losing any stars, i.e. earn a total of 57 x 3 = 171 stars. If students needed to take a hint (-1 star) or a peek (-2 stars) on a certain problem, they could earn back the lost stars by completing additional unassigned problems of their choosing.

Students were given the opportunity to take the PSVT:R again after this 6-week period. Students who scored 70% or above earned all 5 pts. To reward both performance and effort, students could also earn "training-based" credit by completing additional training exercises to earn extra points on their SVS grade.

In this paper, training effort is measured by the number of training problems completed, and persistence is measured by the average number of stars per problem. For example, students with the highest persistence would have the maximum average of 3 stars, whereas students who take a hint on half the problems would have an average of 2.5 stars.

Results

A total of 128 students participated in the study. Students who did not complete any training exercises were excluded from this study. Results of the initial PSVT:R assessment are shown in Figure 2. A test score of 70% or higher was considered passing. There were 74 out of 128 who passed the test, for an initial pass rate of 57.8%. There were 33 students with a test score below 60% (novices) and 21 students with a test score between 60 and 69% (intermediates).

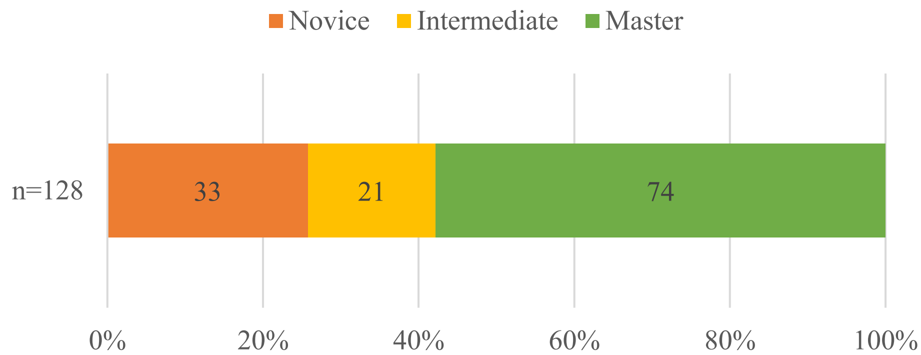

Figure 2. Initial placement results for all students (n=128).

As mentioned previously, all students were assigned a total of 57 problems (approx. 2.5 hours) as the spatial skills training. Figure 3 shows that the amount of training that students completed varied widely, anywhere from 14 to 275 exercises. The level of persistence for most students was quite high, as measured by the average stars (max 3.0).

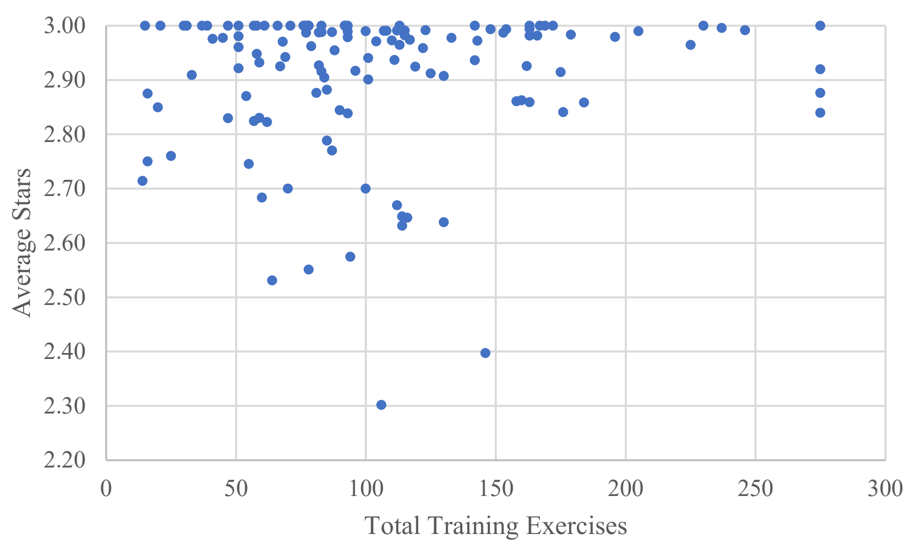

Figure 3. Level of effort (total exercises) and persistence (average stars) in the SVS training by all students (n=128).

The SVS training was effective in improving spatial ability for all three subgroups, as seen in Figure 4. The increase in average test score were significant for novices ($t(33)$=-8.566, p<.001), intermediates ($t(21)$=-4.752, p<.001), and masters ($t(74)$=-7.568, p<.001), as measured by initial and final PSVT:R scores.

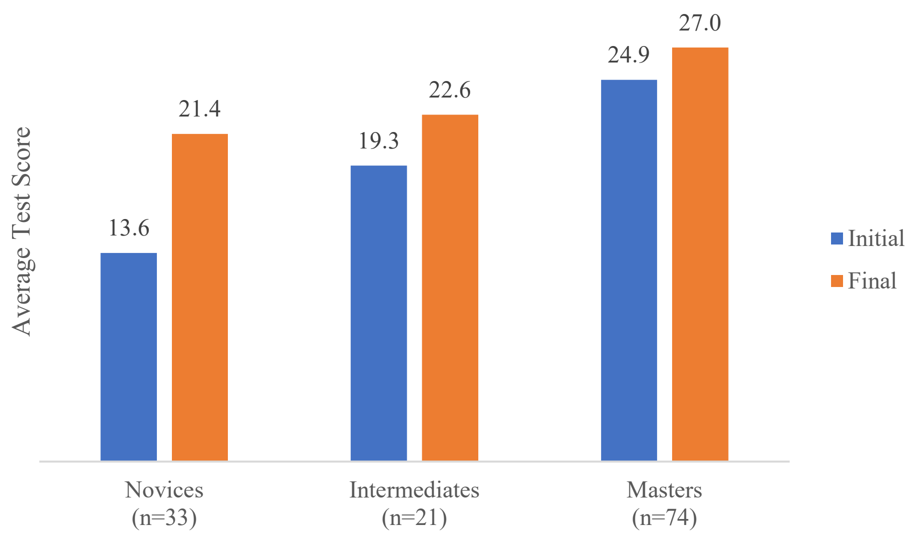

Figure 4. Average test scores for all three subgroups, before and after the SVS training.

Effect of persistence in training on improvement in spatial ability

A correlational analysis between persistence in training and improvement in spatial ability was performed. Average stars was used as a measure of persistence, and the difference between initial and final PSVT:R scores was used as a measure of spatial ability improvement.

As seen in Figure 5, a weak positive correlation between change in test score and persistence was found for novices ($r(33) = .352$, $p = .044$). No correlation was found for intermediates ($r(21) = -.028$, $p = .904$) or masters ($r(74) = .026$, $p = .826$).

Effect of training amount on improvement in spatial ability

A correlational analysis between training amount and improvement in spatial ability was performed. Training amount was measured by total number of exercises completed, and the difference between initial and final PSVT:R scores was used as a measure of spatial ability improvement.

As seen in Figure 6, a weak negative correlation between change in test score and training amount was found for novices ($r(33) = -.331$, $p = .060$). No correlation was found for intermediates ($r(21) = -.077$, $p = .741$) or masters ($r(74) = -.216$, $p = .064$).

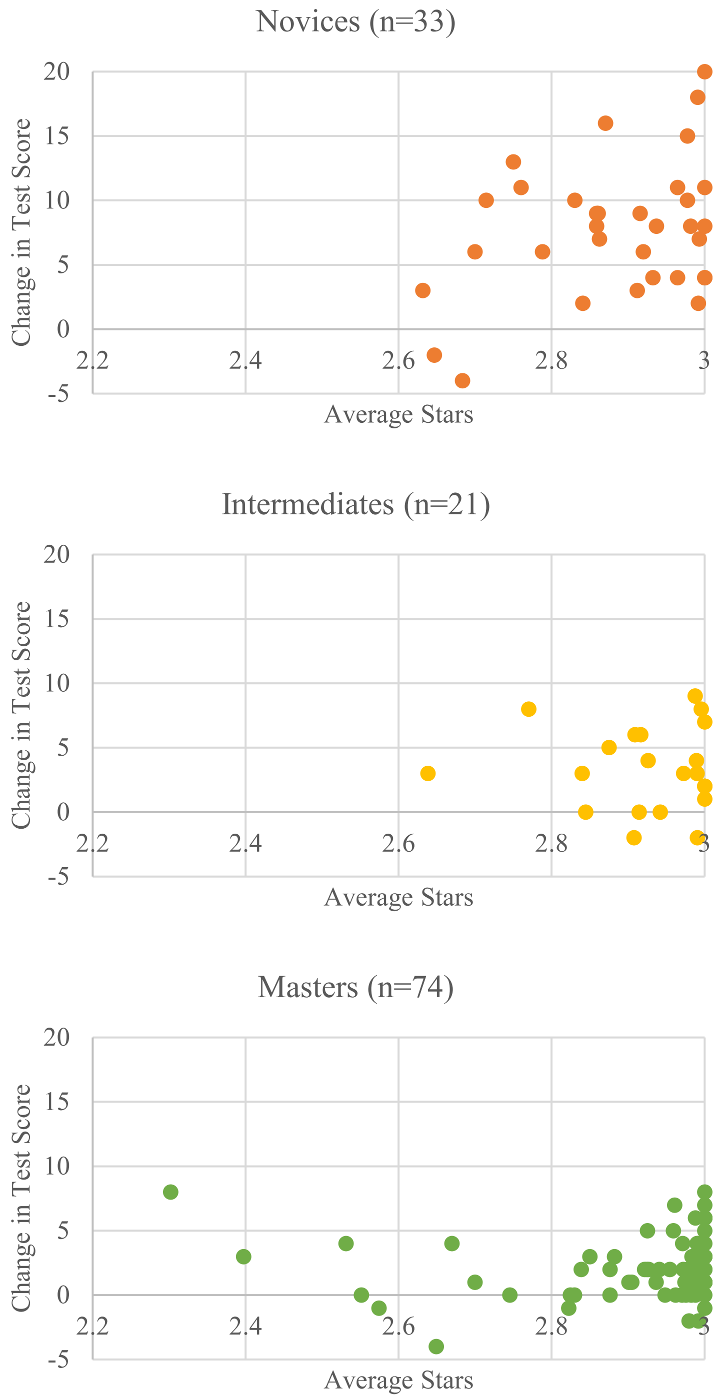

Figure 5. Plots for correlation between persistence (average stars) and change in test score for novices, intermediates, and masters.

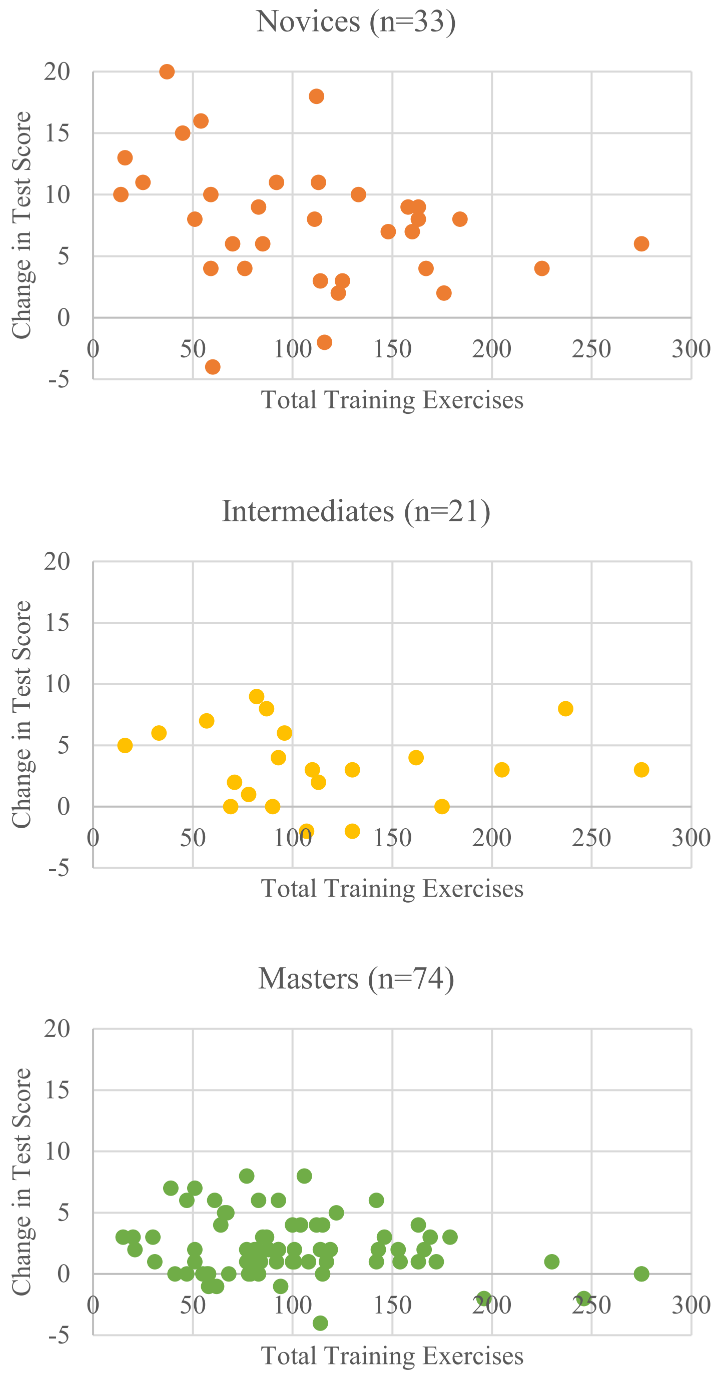

Figure 6. Plots for correlation between training amount (total exercises) and change in test score for novices, intermediates, and masters.

Discussion

Only weak correlations, if any, were identified between persistence, training amount, and gains in test score. Since intermediates and masters have a higher initial test score, they are limited in the amount of improvement that can be demonstrated (maximum increase of 10 pts in test score), which may explain why no correlation with change in test score was identified.

For novices, the positive correlation between persistence and gains in test score was expected, but it is difficult to prescribe any specific minimum level of persistence (average stars) from the results. It can be observed that all novices with average stars of 2.8 and up experienced gains in test score. An average of 2.8 stars corresponds to taking a hint on 20% of the exercises. This is a considerable portion of the training exercises, but students with initially low SVS may require this level of assistance to gradually learn how to properly complete the sketching exercises and ultimately build their SVS.

For novices, the negative correlation between training amount and gains in test score is surprising, as more training would be expected to yield greater gains in spatial ability. The correlation is weak though, and it is likely that the correlation is confounded by many factors, including the range of persistence and initial test score among the novice group. For example, a student who completed a large amount of training (e.g. 200 exercises) but with low persistence would likely see little gain in test score. In addition, initial scores for the novices varied widely from 5 to 17 (out of 30), so the same gain in test score (e.g. 8 pts) would be much more meaningful for novices with very low initial test scores (e.g. 9 out of 30) compared to novices with higher initial test scores (e.g. 15 out of 30). Further separation of novice subgroups (e.g. low vs. high persistence, test score below 50% vs. above 50%) is likely needed to determine a clearer correlation. This however is not feasible for the current study given the limited sample size.

Future work includes identification of alternative metrics for improvement in spatial ability for the intermediate and masters group, as well as larger sample sizes to further distill the student groups into specific ranges of persistence, training amount, and initial test score.

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