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Correlation Between a Student's Performance on the Mental Cutting Test and Their 3D Parametric Modeling Ability

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Introduction

Engineering graphics has historically been viewed as a challenging course to teach as students struggle to grasp and understand the fundamental concepts and then to master their proper application. The emergence of stable, fast, affordable 3D parametric modeling platforms such as CATIA, Pro-E, and AutoCAD while providing several pedagogical advantages, such as the interaction with a dynamic solid model, have also created a few new instructional challenges, such as clarifying the connection between the fundamental engineering graphics concepts and the overarching concepts of robust, parametric 3D solid modeling.

3D parametric modeling platforms offer students the opportunity to manipulate a completed solid model in space – enabling them to actually see views of the model not readily available in a traditional engineering drawing, helping them to build their conceptual modeling frameworks. However, simply completing 3D models does not properly develop spatial visualization skills (Hamlin et al., 2006), the theory of parametric modeling must be thoughtfully integrated into the curriculum so it scaffolded by spatial visualization theory. One of the more common assessment instruments for spatial visualization is the Mental Cutting Test, (MCT). There has been a little research on the relationship between the MCT and modeling ability /maturity, specifically the organization and order of the specification tree/model browser of 3D solid models. This paper presents the results of such a study. 219 first-year engineering students participated, a significant relationship was found between high performance on the MCT and 3D modeling ability.

Method

A study was conducted at Embry-Riddle Aeronautical University in the fall of 2011 to investigate the correlation between a student's performance on the MCT and the quality of their 3D modeling structure. This research comprised 219 students enrolled in the introductory graphical communications course, EGR 120.

Students were asked to complete two common modeling assignments for this study, Figure 1. The first was given during the initial week of modeling instruction and the second was given during the fifth week. The solid models were chosen for several factors. The first model, the image on the left, had several elements, the two concentric

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holes, the three rounded ends, and the elongated hole on the top vertical surface, which would quickly reveal the level of modeling maturity and understanding. The second model, the image on the right, incorporated the original features plus several new elements - the raised boss, the embedded, elongated cylinder, the centered, lower channel, and the finishing fillets. The models were given as part of the students' regular assignments; only the course instructors knew these assignments were to be part of this study. The specification tree of each model was evaluated closely to determine the maturity of the modeling approach and structure.

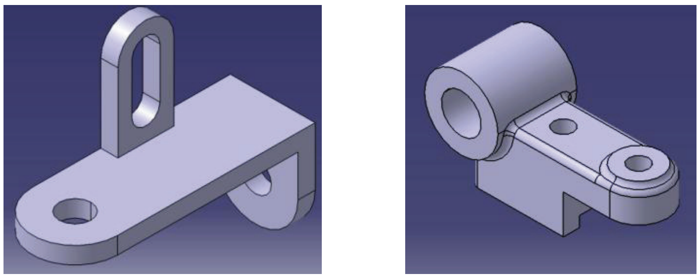

Figure 4. Two Common Solid Modeling Projects.

Figure 2 shows two example specification trees for the first CAD model. The one on the left denotes a lower level of understanding as the model is divided into three distinct pieces and all detail features, such as the corner fillets and holes, are embedded in the base sketches. This structure is indicative of a cursory understanding of the software, as many of the direct modeling commands (hole, pocket, and tri-tangent fillet) were not utilized. This approach does not lend itself well to assembly integration, modification, or revision and is often plagued with waterfalling update errors.

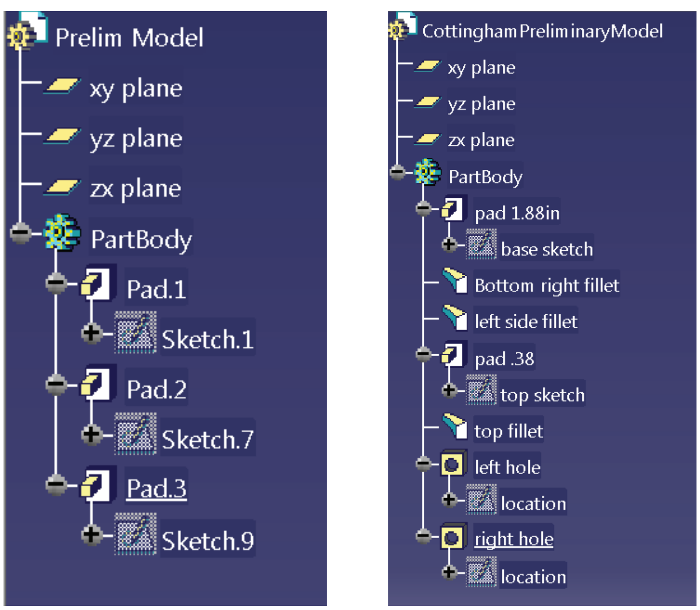

Figure 5. Example Specification Trees.

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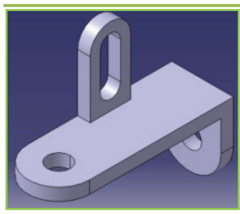
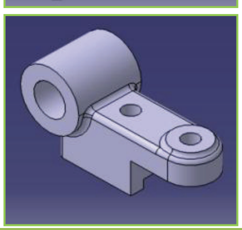
The structure specification tree on the right with its ordered detail elements of the solid model as features (hole and tri-tangent fillet) instead of sketch elements indicates a much deeper understanding of modeling and organization. The specific order is another indication of the deep understanding of the modeling process and how to best leverage it, note the tri-tangent fillets were placed before the concentric holes which reduced the required number of placement constraints for the holes.

Results

Correlations between student scores on the MCT (n= 219) and the individual modeling projects were calculated using SPSS 20 and are shown in Table 1. There was a statistically significant medium correlation between the MCT pre-score and both solid modeling projects. Table 2 presents the correlation factors between student performance on the MCT and the five sections of the rubric. For all findings statistical significance of $p < 0.05$ is denoted by * and $p < 0.01$ is denoted by **.

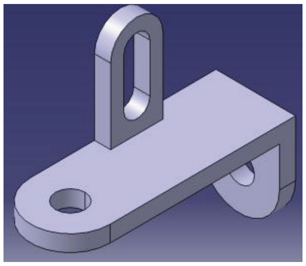
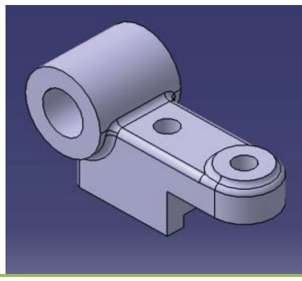
Table 1. Correlation between Pre-Test Score and Two Modeling Projects.

	MCT (n = 219)
	r = 0.32*
	r = 0.36**

Results from the rubrics were recorded for both of the common modeling assignments. Values for each of the sections of the rubric were input as numerical values. A Principal Component Analysis, PCA, was performed on the rubric section scores using SPSS 20. With this analysis, multipliers for each section of the rubric were obtained so that the composite score for each student on a particular rubric could be determined. Use of these multipliers accounted for more than 50% of the variability between the rubrics. Correlations were computed between the rubric scores, the model scores, and the MCT score and are presented in Table 2.

ISSN: 1949-9167

Table 2. Correlation Factors between Solid Models and MCT Score.

Solid Models	Rubric	MCT
	**First Solid Model**	
	Approach	r = 0.3933*
	Structure	r = 0.1865*
	Accuracy	r = 0.4182**
	Robustness	r = 0.2457**
	Creativity	r = 0.2108*
	**Second Solid Model**	
	Approach	r = 0.3001**
	Structure	r = 0.1782*
	Accuracy	r = 0.3910*
	Robustness	r = 0.2994**
	Creativity	r = 0.3654*

Discussion

The correlation factors in Table 1 are between student performance on the MCT and overall grade for each model. Both of the modeling projects had a medium positive correlation with the MCT, indicating that students who performed better on the MCT had more mature 3D modeling frameworks than those students who did not perform as well on the MCT. These findings support Feng, X., Morgan, C., & Ahmed, V. (2004) theorized connection between the MCT and modeling ability, Hamlin et al.'s (2006) and Tsutsumi's (2010) previous research which also suggest the MCT may be a better predictor of students' 3D modeling skill than the more commonly used PSVT:R, the Purdue Test of Spatial Visualization: Rotations. This may be because the MCT requires students to identify the 2D cross section of a provided part while the PSVT:R requires to students to identify the proper orientation of a solid, of these two tasks the MCT more closely relates the theory and approach of solid modeling.

The correlation factors presented in Table 2 are between student performance on the MCT and the five sections of the rubric. There was significant relationship between performance on the MCT and the each of project sections. Approach is defined by shape of the base, or first sketch, the measured correlations are .3933* and .3001*. Structure is measured by the organization and detail included in the specification tree, the reported correlations are .1865* and .1782*. Accuracy is measured by comparing the final model dimensions to the provided handout, the reported correlations are .4182** and .3910*. Robustness is indicated by the type of constraints placed in the base sketch and the associations in the subsequent detail sketches, the measured correlations are .2457** and .2994**. Creativity is indicated by selection of modeling commands and the order in which they are executed; the reported correlations are .2108* and .3654*.

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These results support the findings of Hamlin et al. (2006) where they found a correlation between the MCT and the capability to learn and use 3D modeling software. These findings are also supported by the presented results in Tsutsumi's (2010) work. These results may be indicative of the close relationship between the skills measured by the MCT and creating solid models, both require the ability to discern the correct 2D profiles associated with a solid model.

The literature does suggest a connection between the MCT and 3D modeling ability, and it appears that this research has identified the same association. However, little of the previous research has included a detailed and structured analysis on the specification tree as a measure of modeling approach. Instead much of the published literature has compared other factors against student performance on the MCT. This is the first time this type of analysis has been conducted.

It appears that performance on the MCT may be an effective predictor of student success in 3D modeling. Certainly an area of future research would be a deeper investigation into students' modeling frameworks and their performance on the MCT.

References

Feng, X., Morgan, C., & Ahmed, V. (2004). *Developing visualisation skills - a virtual spatial training (VST) system.* Paper presented at the Conference on Contruction Applications of Virtual Reality, Lisbon, Spain.

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