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Developing 3D Modeling Courses for Online Teaching: Instructional Technologies to Consider

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Abstract

The ability to develop 3D modeling courses for online instruction has existed for years. Due to the instructional complexity of 3D modeling, few have sought to develop these courses for online teaching. In an effort to better understand the components necessary for effective course development, this study collectively aggregated information on several areas that directly impact student response and retention in online environments; these areas included Learner-Centeredness, Course Design (including instructional and interactive technologies), and Drawing and Modeling Content. This paper describes and presents data associated with the instructional and interactive technology components retained from the study's Course Design category.

Introduction

Graphics has long been a language within itself, containing orthography, grammar, style, idioms, and abbreviations (French, 1976), and throughout time has been the method in which engineering prefers to communicate in order to successfully convey and generate design ideas (Barr, 2004). Over the last two decades the profession of engineering graphics has witnessed major shifts in the programs of study, as well as the content areas being taught. With the introduction of computer technologies, engineering graphics education has been significantly influenced, not only altering the curricula, but also the instruction of individual courses (Barr, 2004; Clark, 2001). Considering these technological innovations, it is essential that engineering graphics education moves forward considering alternative methods of instruction (Harris & Meyers, 2007). Engineering graphics educators must not only consider the traditional class settings and methods of instructional delivery, but must also explore nontraditional education environments such as online teaching and learning.

Clark, Petlick, and Scales (2004) noted that for engineering and technical graphics, the greatest advancement toward course teaching has been the development of online instruction and process tutorials. Because development of 3D modeling courses for online instruction is hardly prevalent, there exist the need to more lucidly identify components for developing and implementing a quality online course. Instructional and interactive technologies play an identifiable role in course development in engineering and technical graphics and warrant specific distinction in framed investigations.

Totten and Branoff (2005) suggested that when developing online courses for engineering graphics, graphics educators are specifically faced with challenges such as determining appropriate and effective methods to demonstrate software, developing instructional materials that are primarily comprised of graphic imagery, and ascertaining the most accurate and adequate processes for assessing student work; all of which must be resolved in order to develop a quality online modeling course. The most challenging issues are those that relate to the technological tools needed to address instructional problems while adhering to instructional design principles for online learning and theories of adult learning (Connolly & Maicher, 2003).

This paper highlights the consensus results from a modified three-round web-based Delphi process utilizing a panel of engineering graphics educators and professionals. Identified are the instructional and interactive technologies that should be considered or included when developing and/or teaching introductory 3D modeling or comparable engineering design graphics in the online environment. The remaining components are a part of a final inventory of best practices for developing online introductory 3D modeling courses.

Instructional Technologies for Online Learning

Because technology is rapidly evolving, more tools for interaction and collaboration on the web have been made available. Anderson (2008) described the web as a quickly changing mechanism that at one time was defined from a context of text-based communications, content, and interactions. However, with advancements in technological tools, the web can now be viewed as a mechanism that supports all forms of media. In this dynamic, web-based learning environment, content can be electronically constructed and tailored to meet the needs of the learner. It also helps to assemble web-based learning communities and provides opportunity for learning to continuously revolve around the designated learning tasks (McCombs & Vakili, 2005).

When published to the web, online learning can integrate various types of technologies for synchronous or asynchronous communications. Chickering and Ehrmann (1996) outlined seven principles for such implementation based on good practices for teaching and learning. The principles included encouraging contact between students and faculty, developing reciprocity and cooperation among students, using active learning techniques, giving prompt feedback, emphasizing time on task, communicating high expectations, and respecting diverse talents and ways of learning. These seven principles, in accordance with the course learning objectives, will ultimately assist in determining the justifications for integrating specific technologies.

With advances in technology and the rapid growth of online learning, the need to employ more interactive tools for learning has taken center stage. Utilizing the Internet as a tool for online learning and communication, in accordance with Chickering and Ehrmann's (1996) seven principles, grants instructors the opportunity to rethink their instructional delivery. As the Internet continues to cultivate individual expression, it also promotes a forum for collaborative learning (Huffaker, 2004) through the use of social software or social networking tools. Rollett et al., (n.d.) defined social software as a shared medium that permits users to independently or collaboratively exchange knowledge and publish or display those thoughts utilizing the web. User-friendly applications designed for networking within an online environment (Burgess, 2003) have added value to educational settings (Beldarrain, 2006), particularly those in higher education.

After the development of the first generation of social software, which included chat rooms and discussion boards, Beldarrain (2006) noted that the second-generation of Web tools would dramatically increase interaction. Collectively identified as Web 2.0 technologies, blogs, wikis, podcasts, application sharing, mobile applications, social bookmarking, and digital storytelling, have changed the landscape of social and professional networking and providing learners and educators the opportunity to generate information collectively through social interactions (Maloney, 2007). Unlike traditional methods of information distribution, Web 2.0 technologies make sharing content expeditious (Dearstyne, 2007). It also permits users to not only be "consumers of information" (Cole, 2009, p. 141), but also publishers of information that can be in "partnership with others" (Cole, 2009, p. 141). These technologies can be utilized unaided or in conjunction with other applications.

Web 2.0 technologies have significantly assisted in producing effective learning environments and establishing communities of practice in post-secondary education through continuous individualized interactions and group collaborations. The uses of these technologies are fostering knowledge construction through effective and communal learning, and individual publication, which support the pedagogical approaches to learning (Ferdig, 2007; Beldarrain, 2006). Paralleling Ferdig (2007) and Beldarrain (2006), Totten and Branoff (2005) also stated that with the advancements in technology, the development of Learning Management Systems have been greatly influenced therefore making a variety of tools and instructional solutions available for a multifaceted approach to teaching and learning. Technology has now become a central component to learning in online environments.

Methodology

In an effort to better understand the components necessary for effective course development and implementation, this study collectively aggregated information across several areas related to online course development. The original study began with nine categories and was later modified to the three categories discussed in this paper. The three categories include information that directly impact student response and retention in online environments; these areas are Learner-Centeredness, Course Design (including instructional and interactive technologies), and Drawing and Modeling Content. Again, the overall goal of this research was to utilize a modified three-round Delphi process to reach consensus on the most effective components to be utilized for developing and teaching introductory 3D modeling in an online environment. All remaining components were included in a final inventory of best practices for developing online introductory 3D modeling courses. Although the results of the study yielded forty components spanning the three categories, this paper describes and presents data associated with the instructional and interactive technology components retained from the Course Design category only.

The Modified Delphi

The Delphi process began with soliciting participants for an expert and review panel from the Engineering Design Graphics Division of the American Society of Engineering Education and the American Design Drafting (Digital) Association. Potential participants were provided a link via email to the study's Demographic Questionnaire. The results of the questionnaire are located in Table 1. Based on their responses to a myriad of questions regarding their qualifications and experiences in the areas of online course development and engineering design graphics content knowledge and teaching experiences, expert and review panel participants were selected. While the expert panel was responsible for submitting responses to each of the Delphi questionnaires, participation as a review panel member held the responsibility of examining the clarity, format, and accessibility of each questionnaire developed, therefore eliminating any bias that could possibly be displayed from the researcher. Expert and review panel members remained anonymous to one another throughout the study in order to avoid influence or authority over another.

Following the selection or participants, data was collected utilizing an iterative approach for collecting and analyzing responses (a modified three round web-based Delphi methodology). The three-rounds of questions were provided in sequence. Since the overall goal of the Delphi is to achieve consensus from the expert panel (Linstone & Turoff, 2002), the responses for each round were compiled and organized for each subsequent round (Colton & Hatcher, 2004), retaining and eradicating data throughout the Delphi process.

The first round of the Delphi included categories and open-ended questions containing information about key elements of instructional design, drawing and modeling principles, and instructional and interactive technology requirements. The structure of the first round was to provide participants the opportunity to keep, reject, or modify the provided categories and components, and provide any additional information to be considered in the subsequent round.

The second round of the Delphi included rating of the results tabulated from round one. Panel experts used a Likert scale ranging from one to five, acknowledging agreement or opposition for each component. Likert scale classifications were as follows: strongly agree, agree, neutral, disagree, and strongly disagree. Although modifications were no longer required for each category or component presented in the round two questionnaire, expert panelists were provided an editable text field for the insertion of comments or suggestions, or to input additional components they believed should be included in the round three questionnaire.

After examining the data utilizing the Likert scale ratings, the Cronbach's Alpha analysis was employed. This analysis was used to determine which components were retained or extracted for the final expert solicitation; titled round three Delphi questionnaire. The Cronbach's Alpha analysis is an internal consistency reliability technique that can be utilized to validate the reliability of a set of entities, or in this case, components rated by multiple participants (Osborne, 2008; Bland & Altman, 1997). The coefficient alpha (α) typically ranges between negative infinity and one. Therefore, a significant alpha is based on its proximity to one, which asserts that the closer the alpha value is to one, the greater the internal consistency (Gliem & Gliem, 2003; Graham et al., 2003). This also signifies consensus or agreement amongst participants or expert panelists (Graham et al., 2003). The alpha value used to determine acceptance or deletion of components was .70 (Garson, 2011; Bland & Altman, 1997; Nunnelly & Bernstein, 1994).

Round three of this modified Delphi study was the final round to determine if consensus was being achieved. The data collected in this round was analyzed utilizing a Chi-Square statistical analysis. Components were placed in a contingency table to indicate the number of collected responses for the acceptance or rejection of the component. In order to determine the components that would remain for the final inventory, a probability value for each component was determined. To calculate the probability value, the Chi-Square statistic with one degree of freedom was used. Components with a probability value of less than .05 were retained for the final inventory of best practices.

Results

Fifty-two candidates responded to the Demographics Questionnaire, in which 62% (N=32) of the individuals qualified and were selected for participation. From the qualified pool of 32 experts, three individuals were randomly selected for the review panel.

Table 1. Demographic Information for Expert Panel

Description	Number	Percentage
Title/Position		
Engineering Educator	8	28%
Engineering Graphics Educator	11	38%
Technology Educator	7	24%
Other	3	10%
Total	29	100%
Highest Degree Obtained		
Bachelors Degree	1	3%
Masters Degree	15	52%
Doctoral Degree	13	45%
Total	29	100%
Professional Memberships		
2 or more years	29	100%
Status		
Currently teaching, developing, or implementing engineering graphics courses	25	86%
Past experience teaching, developing or implementing engineering graphics courses	4	14%
Total	29	100%
Course Development (in years)		
3 or more	8	28%
2-3 years	11	38%
2 years or less	7	24%
No Response	3	10%
Total	29	100%

Table 1. Demographic Information for Expert Panel (cont)

Description	Number	Percentage
Fully Online Teaching/Development (in years)		
3 or more	8	28%
2-3 years	2	6%
2 years or less	4	14%
None	15	52%
Total	29	100%
Hybrid Online Teaching/Development (in years)		
3 or more	14	48%
2-3 years	0	0%
2 years or less	13	45%
None	2	7%
Total	29	100%

Round 1 of the Modified Delphi Study

The first round of the Delphi included two initial components in the original category in which panel participants were asked to keep, reject, or modify. Participants were also asked to provide additional instructional and/or interactive technologies to be included in the round two questionnaire. The components outlined were 1) Online 3D modeling courses should use application sharing through synchronous communications to demonstrate design software such as SolidWorks and 2) 3D modeling courses taught online should use demonstration videos and voice-over PowerPoint. Although the expert panel was comprised of 29 participants, round one yielded overall 55% (n=16) participation. Of the 16 participants, 81% (n=13) elected to keep both components and 19% (n=3) believed both components should be revised. The revisions are listed in Table 2.

Table 2. Revised Categories & Components for Round 2

Initial Category or Component	Revised Category or Component
3D modeling courses should use application sharing through synchronous communications to demonstrate design software's such as SolidWorks.	Application sharing should be used to demonstrate design software.
3D modeling courses taught online should use demonstrations videos and voice-over PowerPoints.	3D modeling courses taught online should use demonstration videos and voice-over PowerPoints as an instructional option.

The round one questionnaire also provided editable text fields for expert panelists to type additional comments, suggestions, and/or components they believed should be considered for the round two questionnaire. One new component was suggested for instructional/interactive technologies - 3D modeling courses taught online should include interactive exercises that react to student input and provide constructive, context-sensitive feedback to the student.

Round 2 of the Modified Delphi Study

This round yielded a 41% (n=12) response rate based on the total number of participants (29) and a 75% return rate from those that participated in round one.

Based on the procedures for calculating Cronbach's Alpha in tandem with the literature regarding the grouping of the subject matter used in each category overall, several categories and components were combined and renamed to meet the criteria. In addition to the original two components (Table 2) and the suggested new component, this category now included 18 additional components. The reliability statistics for this category (21 components) displayed an original reliability coefficient alpha of .878 and a total mean of 79.42. Alpha values for the group of components ranged from .861 to .879, all well above the targeted value (α=0.70). A high overall and individual alpha signified greater internal consistency reliability amongst the components, meaning less variability amongst the components in the list. Because the overall alpha value was significantly greater than the targeted value of .70, a stepwise deletion was not required.

For round two some rephrasing of the components was provided, but more importantly 15 new components about instructional and interactive technologies were suggested to be added to the round three questionnaire. The round three category *Course Design* now included 36 components. The new instructional technology components are outlined in Table 3.

Table 3. Additional Instructional Technology Components for Round 3

Online modeling courses should employ collaborative tools such as wikis to allow learners to discuss, construct, or demonstrate understanding of course topics.
Online modeling courses should utilize discussion boards to pose thoughts/questions, evoke responses, and/or address issues.
Online interactive whiteboards should be used in online modeling courses to facilitate real-time collaborations between learners or between the course instructor and the learners.
Blogs should be included in online modeling courses to document processes, share opinions, provide commentary, and/or personal reflections about course projects, assignments, or questions posed by the instructor.
Live (real-time, synchronous) tools should occasionally be included in online modeling courses to facilitate course presentations, communications, and/or establish a greater sense of personal engagement between the learners and the course instructor.
Social bookmarking tools should be utilized to collectively identify and construct an inventory of online modeling resources/websites.
Online interactions include accessing content through a course website.
Application sharing should be utilized to assess the student's knowledge of software application.
Real-time applications for the creation of process flows and diagrams should be included in online instruction.
Modeling content delivered asynchronously should include lecture capture videos.
Course content should be displayed using voice-over PowerPoints.
Demonstration videos displaying hands-on sketching practices/techniques should be included in online instruction.
Screencasts should be included in online modeling content to visually present recorded step-by-step processes/demonstrations of course software usage.
Online modeling courses should incorporate simulations/animations to demonstrate the internal processes of model building.
Podcasts should be used to provide audible explanations, commentary, and/or reflections on course assignments, course projects, and/or overall student progress.

Round 3 of the Modified Delphi Study

Round three, the final round of this Delphi study was employed to determine the final consensus for components to be considered or included in the final inventory of best practices. Forty-five percent (n=13) of the total number of respondents (N=29) completed and submitted their responses. The data collected in this round was analyzed utilizing a Chi-Square statistical analysis. Components were placed in a contingency table to indicate the number of collected responses for the acceptance or rejection of the component. Table 4 outlines the instructional and interactive technologies included in the *Course Design* category. Table 4 also identifies the technologies eliminated from the final inventory of instructional and interactive technologies. Two asterisks denote components with a probability value greater than .05. These components were eliminated from the final inventory of best practices.

Table 4. Chi-Square Analysis, Instructional & Interactive Components Accepted or Rejected

Components	N	Acpt. (%)	Rejct.(%)	X^2	p<.05
1. Content delivered asynchronously should include multiple methods of delivery to meet individual learning styles.	13	10 (76.9)	3 (23.1)	3.769	.10**
2. Online interactions with course content include the use of a Learning Management System (LMS).	13	12 (92.3)	1 (7.7)	9.308	.01
3. Application sharing tools should be used for live demonstrations of course software.	13	12 (92.3)	1 (7.7)	9.308	.01
4. Interactive exercises that react to student input and provide constructive, context-sensitive feedback to the student should be included in online instruction.	13	10 (83.3)	2 (16.7)	5.333	.05
5. Online modeling courses should employ collaborative tools such as wikis to allow learners to discuss, construct, or demonstrate understanding of course topics.	13	10 (76.9)	3 (23.1)	3.769	.10**

Note: **Denotes components with a probability value greater than .05. These components were eliminated from the final inventory of best practices.

Table 4. Chi-Square Analysis, Instructional & Interactive Components Accepted or Rejected (cont)

Components	N	Acpt. (%)	Rejct.(%)	X^2	p<.05
6. Online modeling courses should utilize discussion boards to pose thoughts/questions, evoke responses, and/or address issues.	13	12 (92.3)	1 (7.7)	9.308	.01
7. Online interactive whiteboards should be used in online modeling courses to facilitate real-time collaborations between learners or between the course instructor and the learners.	13	10 (76.9)	3 (23.1)	3.769	.10**
8. Blogs should be included in online modeling courses to document processes, share opinions, provide commentary, and/or personal reflections about course projects, assignments, or questions posed by the instructor.	13	6 (46.2)	7 (53.8)	.077	.80**
9. Live (real-time, synchronous) tools should occasionally be included in online modeling courses to facilitate course presentations, communications, and/or establish a greater sense of personal engagement between the learners and the course instructor.	13	10 (76.9)	3 (23.1)	3.769	.10**
10. Social bookmarking tools should be utilized to collectively identify and construct an inventory of online modeling resources/websites.	13	7 (53.8)	6 (46.2)	.077	.80**
11. Online interactions include accessing content through a course website.	13	12 (92.3)	1 (7.7)	9.308	.01

Note: **Denotes components with a probability value greater than .05. These components were eliminated from the final inventory of best practices.

Table 4. Chi-Square Analysis, Instructional & Interactive Components Accepted or Rejected (cont)

Components	N	Acpt. (%)	Rejct.(%)	X^2	p<.05
12. Application sharing should be utilized to assess the student's knowledge of software application.	13	11 (84.6)	2 (15.4)	6.231	.05
13. Real-time applications for the creation of process flows and diagrams should be included in online modeling instruction.	13	9 (69.2)	4 (30.8)	1.923	.20**
14. Modeling content delivered asynchronously should include lecture capture videos.	13	11 (84.6)	2 (15.4)	6.231	.05
15. Course content should be displayed using voice-over PowerPoints.	13	10 (76.9)	3 (23.1)	3.769	.10**
16. Demonstration videos displaying hands-on sketching practices or techniques should be included in online instruction.	13	11 (84.6)	2 (15.4)	6.231	.05
17. Screencasts should be included in online modeling content to visually present recorded step-by-step processes/demonstrations of course software usage.	13	11 (84.6)	2 (15.4)	6.231	.05
18. Online modeling courses should incorporate simulations/animations to demonstrate the internal processes of model building.	13	13 (100)	0 (0)	13.000	.001
19. Podcasts should be used to provide audible explanations, commentary, and/or reflections on course assignments, course projects, and/or overall student progress.	13	6 (46.2)	7 (53.8)	.818	.50**

Note: **Denotes components with a probability value greater than .05. These components were eliminated from the final inventory of best practices.

As a final inventory of agreed upon instructional technology components, nine instructional technology components were selected based on a p-value of .05 or less (Table 5).

Table 5. Instructional Technology Components Retained for Final Inventory

Online interactions with course content include the use of a *Learning Management System (LMS) or course website.*
Application sharing tools should be used for live demonstrations of course software.
Interactive exercises that react to student input and provide constructive, context-sensitive feedback to the student should be included in online instruction.
Online modeling courses should utilize *discussion boards* to pose thoughts/questions, evoke responses, and/or address issues.
Application sharing tools should be utilized to assess the student's knowledge of software application.
Modeling content delivered asynchronously should include *lecture capture videos.*
Demonstration videos displaying hands-on sketching practices or techniques should be included in online instruction.
Screencasts should be included in online modeling content to visually present recorded step-by-step processes/demonstrations of course software usage.
Online modeling courses should incorporate *simulations/animations* to demonstrate the internal processes of model building.

Note: Italics denote the technology or describes the technology to be used.

Conclusions

As the educational landscape continues to change, the methods used to convey instruction are evolving as well. While the literature has shown that incorporating various instructional and interactive technologies such as wikis and online whiteboards, real-time applications, live chat and communications, podcasts, etc., should be considered or included in instruction to create a richer, more dynamic learning environment, the expert panelists in this study did not strongly and collectively elect any of these instructional technology tools (Table 4). Of the 19 instructional technology components 47% (n=9) were retained for the final inventory and most of the collaborative tools suggested for inclusion in round three were eliminated.

It is important to note the elimination of component one: "content should be delivered asynchronously utilizing multiple methods of delivery". Multiple methods of delivery are considered to be multi-dimensional, meaning that information is distributed and received through multiple channels (Bonk & Wisher, 2000). When considering multiple channels to disseminate, exchange, and construct information and knowledge, many of the Web 2.0 tools that were identified and outlined in this study could facilitate those processes. It can be concluded that a cause for elimination of component one may be based on one's individual view of how to utilize these tools in instruction. Many of the interactive/collaborative tools could be viewed as tools to use synchronously, not asynchronously. Therefore, expert panel members may deem the use of those tools, although effective for transmitting and receiving information multi-dimensionally, as inappropriate for asynchronous learning.

Although the expert panel members did not state any reasons for eliminating component one or any of the other interactive/collaborative tools, additional causes for elimination may include insufficient time for implementation, the cost associated with integrating the technology tool into a 3D modeling course, and/or lack of knowledge of the capabilities of the technology tools. Other viable options may include previous unconstructive experience utilizing the tools, and the tools inadequacy in a 3D modeling environment.

While this inventory does not exhaust instructional technology that currently exists, it does provide insight about current instructional and interactive technologies that should be incorporated into, or at least considered, for current and future instructional practices. Engineering graphics educators seeking to transition from face-to-face to online instruction or revise an existing introductory 3D modeling course can utilize this inventory as a guide or blueprint for course development.

References

Anderson, T. (2008). Teaching in an online learning context. *Theory and practice of online learning*. Canada: Athabasca University. Retrieved from http://cde.athabascau.ca/online_book/ch11.html

Barr, R. (2004). The current status of graphical communication in engineering education. Proceedings of the 34th *American Society of Engineering Education Frontiers in Education Conference*, *Savannah, Georgia*, October 20-23, 2005.

Beldarrain, Y. (2006). Distance Education Trends: Integrating new technologies to foster student interaction and collaboration. *Distance Education*, *27*(2), 139-153.

Bland, J.M. & Altman, D.G. (1997). Statistics notes: Cronbach's alpha. *British Medical Journal*. *314*(7080), 572.

Bonk, C. J., & Wisher, R. A. (2000). *Applying collaborative and e-learning tools to military distance learning: A research framework.* United States Army Research Institute for the Behavioral and Social Sciences. Retrieved from http://php.indiana.edu/~cjbonk/Dist.Learn%20(Wisher).pdf

Burgess, L. (2003). WebCT as an E-learning tool: A study of technology students' perceptions. *Journal of Technology Education, 15*(1).

Chickering, A., & Ehrmann, S.C. (1996). Implementing the seven principles: Technology as lever. *American Association for Higher Education, 39*(7), 3-6.

Clark, A. (2001). Technical Data Presentation: A New Course Offering for Engineering Graphics Programs. *Proceedings of the Southeast Section of the American Society for Engineering Education Annual Conference, Gainesville, Florida,* April 7-9, 2002.

Cole, M. (2009). Using Wiki technology to support student engagement: Lessons from the trenches. *Computers & Education, 52*, 141-146.

Colton, S. & Hatcher, T. (2004). The web-based Delphi research technique as a method for content validation in HRD and adult education research. *Paper presented at the Academy of Human Resource Development International Conference (AHRD), Austin, Texas*, March 3-7, 183-189.

Connolly, P. E., & Maicher, K. R. (2003). Instructional design of a web-based engineering graphics tutorial. *Proceedings of the 58th Annual Engineering Design Graphics Midyear Meeting, Scottsdale, Arizona,* November 16-19, 89-97.

Dearstyne (2007). Blogs, mashups, and wikis: Oh my! *Information Management Journal*, *41*(4), 24−33.

Ferdig, R. (2007). Examining social software in teacher education. *Journal of Technology and Teacher Education*, *15*(1), 5−10.

French, T. E. (1976). The Educational Side of Engineering Drawing. *Engineering Design Graphics Journal*, *40*(3), 32-35.

Garson, G.D. (2011). *Scales and Standard Measures*. Retrieved from http://faculty.chass.ncsu.edu/garson/PA765/standard.htm

Gliem, J.A., & Gliem, R.R., (2003). Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales. *Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education, Columbus, Ohio*, October 8-10, 2003.

Graham, B. Regehr, G. & Wright, J.G., (2003). Delphi as a method to establish consensus for diagnostic criteria. *Journal of Clinical Epidemiology*, *56*, 1150-1156.

Harris, L. A. & Myers, F. (2007). Engineering Design Graphics: Into the 21st century. *Engineering Design Graphics Journal*, *71(3),* 20-34.

Huffaker, D. (2004). *The* educated blogger: using Weblogs to promote literacy in the classroom. *First Monday, 9(6).* Retrieved from http://firstmonday.org/issues/issue9_6/huffaker/index.html

Linstone, H., & Turoff , M. (2002). *The Delphi Method: Techniques and Applications*. Retrieved from http://www.is.njit.edu/pubs/delphibook/index.html

Maloney, E. (2007). What Web 2.0 can teach us about learning. *Chronicle of Higher Education*, *25*(18), B26.

McCombs, B. L. & Vakili, D. (2005). A learner-centered framework for e-learning. *Teachers College Record, 107*(8), 1582-1600.

Nunnally, J.C. & Bernstein, I.H. (1994). *Psychometric theory*. New York: McGraw Hill.

Osborne, J.W. (2008). *Best Practices in Quantitative Methods*. Sage Publications, Inc. Thousand Oaks, California.

Rollett, H., Lux, M., Strohmaier, M., Dösinger, G. and Tochtermann, K. (n.d.). The Web 2.0 way of learning with technologies. *International Journal of Learning Technology*, X, (Y), 000–000.

Scales, A., Petlick, J.H., & Scales, A.Y. (2004). A Study of Current Trends and Issues for Graphics Education: Preliminary Results from a Five-Year Follow-up Survey. *Proceedings of the 54th Midyear Conference of the Engineering Design Graphics Division of the American Society of Engineering Education, Williamsburg, VA,* November 21-24, 2004, 67-75.

Totten, R. A. & Branoff, T. J. (2005). Online learning. Research, tools, and best practices. *The Technology Education Journal, VIII*, 4-12.

Online Delivery of Technical Graphics Courses

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Abstract

Distance education has matured significantly as online technologies have become robust and ubiquitous. Once the purview of specialized educational offerings, distance delivery via the Internet is now a strategy embraced by almost every educational institution—from high school and community and technical colleges, to undergraduate and graduate programs at universities. Internet-based instruction has proven a cost-effective means of reaching underserved populations, extending traditional classrooms and schedules, and stretching dwindling resources. This paper reviews the practices employed by the author in delivering a variety of graphics courses via the Internet and proposes "best practices" for future course development.

Introduction

Delivery of instruction at distance is not new; in fact it dates back to the 1700's. More recently, correspondence courses have a rich history in this country and abroad, especially since the realization of universal postal service. However, only since the advent of the Internet, and the corresponding development of easily accessible broadband communications technologies, has distance instruction been, literally, available to anyone, anytime, anywhere on the globe. So, for the purposes of this paper, distance delivery of instruction is inexorably tied to Internet technologies, and is generally called "online education."

Many of the discussion points in this paper are generalized to online delivery; certainly graphics courses present unique issues. However, all the general constraints and considerations can be applied to courses where the delivery method, student learning, and the evidence of accomplishment are graphical.

In 1996, when I first used the Internet to deliver graphics course materials, I had no idea I would eventually be sitting in my home office in Gilbert, Arizona, teaching forty-some computer graphics technology students nearly two thousand miles away. I actually didn't get into university teaching to do this; I always enjoyed being shoulder-to-shoulder with students, first across a drawing table and for the last several decades, across a mouse pad. This has changed. Distance delivery of university instruction is the single most dramatic shift in how we, as graphics content specialists and course designers, go about our business. The future is pretty simple to see: If you are doing distance delivery now, you'll be doing more in the future; if you aren't engaged in distance delivery now, you will be, and soon.

For fifteen years I have taught approximately twenty separate course titles and all have had various online components. In the past decade, I have taught five separate courses in a variety of online modes—from fully online, where I see my students only through Skype office hours—to hybrid offerings where the lecture may be face-to-face (f-2-f) and all labs, quizzes, and demonstrations are available online. Three of the courses might be considered "traditional graphics" courses where instruction is about graphics, and the major product of student learning is graphical output. In all cases, these five existed as traditional f-2-f courses that I had taught before, so for me, the process has been converting existing, smooth-running, traditional classroom courses to online delivery. Which lets me answer the major question.

The Major Question is Answered

A common criticism of online instruction (and by extension, online degree programs) is that they are not as "rigorous" (read good or valuable) as traditional classroom-based courses and programs. Certainly, there are worthless online degrees, just as there are worthless traditional degrees. But delivery mode is but one variable in the course equation. Add to that the subject matter expertise of the instructor and the instructor's pedagogical, organizational, and interpersonal skills. Additionally, add the preparedness of the students and their enthusiasm—factors generally outside the instructor's control—and you can see that this is a multivariate problem.

A significant variable impacting online success is the level of technological expertise needed to effectively deliver, and take, online instruction. The days of showing up to lecture with only your crumpled lecture notes and a fresh stick of chalk are over. The days of expecting that knowledge will be dispensed at 3:30 on M-W-F is done. Where a classroom teacher might only need PowerPoint slides, an online instructor also needs in-depth understanding of computer, Internet, course management systems (CMS), communications technologies, and, emerging social media platforms. Where a traditional student shows up in class "to be taught," an online student must navigate a virtual educational landscape and is in charge of when, and how, they learn.

This increased level of non-subject matter knowledge is the single greatest impediment to adopting online delivery strategies—even when other pressures justify it—and directly impacts eventual student success.

The whole "better" argument is both unproductive and specious. Online instruction is *different* from traditional classroom instruction, just as lecture is different from seminar or laboratory is different from internship. Online is neither by definition better, nor worse. Just as there may be considerable differences in the quality of similarly delivered classroom courses between various universities, an online course *may* be more effective, result in higher and longer-term learning, and produce greater long-term benefits…or it may not. Adopting online delivery because it is "better" is as problematic as *not* adopting online delivery because it is thought to be inferior.

Why then change from traditional classroom to online instruction? There are several commanding reasons.

- **You are told to go online.** I remember when traditional drafting board graphics instructors were pulled kicking and screaming into the digital age. Change was difficult. Some deans solved this by selling the drafting boards over the summer and moving in computers for fall semester. Unless you are close to retirement, you have to get interested in online technologies, and in a hurry.
- **You have an underserved population.** Distance education doesn't have to be far away. Some students live across the street but can't get to campus because of job requirements. Or, your state is sparsely populated and potential students can't relocate to another city to get a degree. Often times on-campus students prefer online courses because it makes scheduling simpler, allows them to take more hours, or take courses that would normally conflict.
- **You have an equipment or space problem.** Online education offloads much of the computer and software headaches from the institution to the student. Maybe not fair, but in a world of dwindling higher education resources, many institutions simply cannot continue to provide the level of computing technology they have in the past. Additionally, capital expenditures for classroom buildings may be at a premium. A lack of classroom space or equipment is justification for considering online delivery.
- **You have an enrollment problem.** This can be an issue of too many students, or, too few. Large graphics programs experience the problem of regularly adding sections as demand increases. If enrollment is capped because classrooms contain a set number of workstations, opening an online section may relieve the problem. Another problem is having too few students to offer a course. An online course may attract campus, off-campus, continuing education, and even students from other universities who will transfer the course back to their home institutions.
- **You have a staffing problem.** This is problematic for faculty. There is no greater overhead for the institution (actually less in terms of utility overhead) in switching a f-2-f class of 25 to an online class of 50. Class capacity creep is a universal outcome of online delivery because there are no physical space requirements. A full-time load of three 25-students sections can easily become four online 40-student sections. If you are

understaffed, and course demand is high, online offerings serve more students without staffing, space, and scheduling problems.

- **You teach a subject that naturally lends itself to online delivery.** In the graphical purview, any course whose subject is essentially *about* computers (CAD, data analysis and presentation, illustration, Web, animation, programming, etc.) is a natural to be *on* computers, and delivered *by* computers. Laboratory courses are universally thought of, incorrectly, as being unsuited for online delivery. Unless you are involved in strictly vocational training, where the manipulation of equipment and artifacts is important, most laboratory experiences can be effectively simulated…as long as you accept that it is the body of knowledge that's important, and not artifact manipulation. Biology, organic chemistry, physics, and other traditionally laboratory-intensive courses are effectively taught online.

Dispelling Falsehoods

Several falsehoods persist in distance education that can be refuted by experience:

It's easy to put a course online. This belief persists among administrators who have no direct experience in online delivery. They must consider it akin to switching classrooms, or at worse, adopting a new textbook. It is my experience that several hundred man-hours are required to put an existing f-2-f course into a form that can be effectively and efficiently delivered online. If you get some summer development money to get your course ready for fall online delivery, you're lucky. Otherwise, you're on your own.

It's cheap to put a course online. Even worse, creating a course *from scratch* is horrendously labor-intensive and expensive. I worked on a FEMA grant that delivered two forty-hour emergency management courses via a SCORM-compliant CMS. No previously developed materials existed. All planning, organization, photos, notes, lectures, narrations, videos…all everything…had to be generated new. The courses cost around $150,000 apiece. At the university, this usually means unpaid "love" time (because you love your job so much).

The university is there to help. You may be lucky to have information or instructional technology assistance. But often this can be more hindrance than help. In my case, my university flirted with a number of online lecture technologies—Producer, Echo 360, Adobe Connect, and several others—without settling on a distance learning standard. Having video lectures in several formats, I gave up, purchased Camtasia myself, and haven't looked back. Do not count on the university to solve your problems for you.

Synchronous instruction is the way to go. This is a myth perpetrated by companies who peddle synchronous technologies. Students *do not* want synchronous distance courses. They enroll in online courses because they *do not* want to be tied to going to class at a certain time (for a number of reasons, both valid and invalid). How do I know this? Students grouse when a twenty-minute quiz is open from 8:00am to 10:00pm on Wednesday. ("I don't have any time on Wednesday!") Several free and robust synchronous video conferencing products are currently available if you need to hold live office hours, or advise students in real time.

It's easy to teach a course online. Getting a course ready for online delivery is an order of magnitude more difficult that the same course delivered in the classroom. After it is up and running, online requires constant attention—like some great machine with valves, handles, adjustments, and required maintenance. True, once an online course has been running several semesters the amount of preparation is significantly reduced. But to effectively run the course and communicate with the class you must be online *every day* with each online class you teach, including weekends and holidays. It's just the nature of the beast. So, you are just like the university president: you work for the university 24/7. As I mention elsewhere, teaching online is the greatest change in our lifetime in how we go about our business.

An online course is easier. (See "The Major Question is Answered," above). An online course is not necessarily, and usually is not, self-paced (a shocking realization for some students). It requires such a higher level of self-discipline, dedication, time management, and technological expertise that independent of the rigor of the subject matter, it is by definition, harder. Tragically, the poorest students have the greatest susceptibility to this.

Things I Have Found Out

The Online Student. In very short order, individuals that have little personal experience with non-digital devices will populate university classes. (You know them. They are your children or grandchildren.) They expect information now, wherever they are, and in a form that is accessible from the latest devices they own. They won't know about records (and view CD's as historical artifacts), or tapes, or maybe even books that have paper pages. They know that libraries exist, but just can't imagine why anyone would get in their car and drive there, when you can just do a search and download the file.

Online instruction intensifies learning problems. If a student (see "easier," above) has problems getting up in the morning, they will probably have problems setting time aside for your online class. If they hate going to lecture, they probably will hate videos. If they never bring their textbook to class, they probably won't refer to the online PDF version. If they have trouble turning their labs in on time, they won't pay attention to when the drop box closes.

There is the issue of "learning styles," a topic covered well in the EDGD literature and in scholarly literature in general. The three accepted styles of visual, auditory, and tactile seemed to encompass just about every way humans might learn. However, online learning requires a so much greater degree of a "self-directed learning style" that some students simply cannot be successful even when the delivery method matches their personal learning style. An "intrinsic" learner (one who doesn't have to be told what or when to learn) can be very successful in an online learning environment. An "extrinsic" learner (one who learns only what is put before them and only when it is delivered) can experience disaster.

In my experience a successful online students exhibits these characteristics:

- **Is adept at time management.** Because most online courses are asynchronous (in my experience the vast number of students will not/cannot be regularly online at a time certain), a successful online student must structure their life so that sufficient time is set aside for course tasks. Descriptors such as self-directed and self-motivated are commonly used.
- **Has adopted various online communications skills.** Communication is key to successful distance learning (see comments in the Online Instructor and Online Course sections below). Checking your e-mail once a day is not sufficient. Checking your course site three times a week is also not sufficient. Failing to enter into discussion boards, blogs, wikis, tweets, or Facebook posts severely limits online communications and success.
- **Understands online etiquette and protocol.** As part of an online community (in this case, an online course) every member must understand what is appropriate and inappropriate behavior in e-mails, discussion groups, blogs, tweets, etc.
- **Has a high technological aptitude.** There is so much technological overhead in taking an online course that regardless of the student's subject matter knowledge, any number of factors may impede learning. From having the appropriate hardware, software, and network connection, to being able to navigate a CMS and use online resources; being flexible when things don't go as planned (slow connection, server down, software crashes, unreadable files), to work-arounds because you are on the road. A successful online student is resourceful, just as a traditional student has to be resourceful when they lose their lab sheet, or miss lecture, or misplace their textbook. Descriptors such as tech- and cyber-savvy are commonly used.
- **Views online course materials as an entry point to more information and learning.** A successful online student will use search technologies to expand their knowledge and enthusiastically share what they discover with their learning community.

The Online Instructor. The online instructor is a conductor. He or she must be able to synthesize a body of knowledge, abstract it for the intended audience, and use whatever technologies are available to deliver it when, where and how it is needed. You are online *every* *day*, including weekends and holidays. You seamlessly move from subject matter expert, to information technologist, to instructional designer.

In my experience a successful online instructor exhibits these best practices:

- **Is a subject matter expert**. In commercial online development, a subject matter expert (SME) is usually paired with an instructional designer and an information technologist. As SME, an online instructor must know enough about instructional design and information technology to distill the body of knowledge into elements that achieve the educational outcomes, but are also pedagogically sound and technologically deliverable.
- **Knows how to ask for help.** Because as a SME you generally are not an instructional designer or an information technologist (and in many cases don't want to be), you have to seek out resources that complement your skill set. This may be within the institution, in an online community, or through self-study. Graphics instructors are in a better position than many academics because we have some knowledge of digital graphics, Web technologies, animation, etc.—all components of online courses.
- **Matches the learning objective with appropriate technology.** Not every topic requires a 3D animation. Not every topic requires a streaming video.
- **Doesn't reinvent the wheel.** Because online courses use an Internet platform, all the resources of the World Wide Web are available. A little research and linking by you accomplishes several ends: a greater breadth of literature and examples than you could ever assemble yourself are available to your students, and, it demonstrates to your students that the course is simply a window into a much larger, and richer, universe of learning.
- **Sneaks up on a completely online course.** You don't have to jump into the deep end of the online pool. You can start with posting your syllabus and schedule of instruction, and by using the course management system's grade book. Then, over a period of a semester or two, you can migrate your lecture notes or slides and assignments and resources, start getting students to submit their work via drop boxes. Follow that up with online quizzes and examinations (taken in class to start, moved to out of class later). With the final addition of video lectures (see note on modularity below) you can go totally online.
- **Seeks out avenues of communication**. The more effectively you communicate with your students the greater success your students will have in the course; as a bonus, they will hold you in higher regard. (Remember the instructor evaluation comments that we always get hammered on: "Doesn't hold enough office hours," and, "Doesn't return graded work on time." Multiply those concerns by about a hundred in an online environment.) This means a multi-channel approach that might include weekly video introductions, pod casts, weekly e-mails, announcements on the course site, discussions, synchronous

advisement via Skype or Google+…anything you can do to remove vagaries as to what students are doing and how; in what is due, in what format and when.

- **Is organized to a fault.** Some instructors get in the habit of running a class week-to-week, handing out a weekly syllabus and copying materials to pass out to students right before the class starts. This is antithetical to an effective online instructor. The higher the level of vagary within an online course, the poorer is student learning. And, the poorer will be your course evaluations.

The Online Course

Most graphics teachers have a "course book," the repository of the syllabus, schedule of instruction, lecture slides and notes, lab sheets and their solutions, references, and possibly examples of previous student work. This is what an accreditation team would ask for during a visit; it's what you would leave your replacement if you move on to another job or to that great CAD lab in the sky. This course book becomes the basis of your online course because most of it has to be available to your online students on the first day of class.

In my experience a best practices online course:

- **Uses the lowest level of technology to do the job**. Don't expect your students to have the same super-broadband connection you have, or the hardware, or software. Don't pick a CMS that requires more technology than is reasonably expected. Don't use media that requires special plug-ins or aps. If a static PDF does the trick, don't use a Flash animation.
- **Is intact and complete on the first day of class**. You may choose to make certain parts of the site unavailable, but it is not best practice to be developing the course site while the course is progressing (see note on sneaking up on online delivery, above). Take quizzes as a simple example. If you have a quiz in week twelve of the semester that you have not made up as of the start of class, include a placeholder (sometimes an empty folder or a document with the name of the quiz). That way when a student is trying to plan an interview trip (or something much less understandable, like mid-semester a vacation) it is there.
- **Is consistently organized, formatted and presented**. Week seven has to look like week two. Information must be in the same or similar locations, in the same format, and called the same. Deadlines are consistent, or at least, presented the same way. Drop boxes are called the same, organized the same, located the same, open and close the same. You use the same colors, page organization, file formats, fonts, font sizes…all in the attempt of reducing vagaries that may inhibit the learning process. (Selfishly, every inconsistency in

your online course can potentially trigger a frantic Sunday night e-mail, something you want to avoid.)

- **Leaves no doubt as to what is due, when, in which data format, and with what file name**. This must be unambiguous. You may choose a central repository for this, or include the information on the calendar, assignment sheet, weekly explanation, weekly e-mail, or drop box explanation, to name a few locations.
- **Is built in a modular fashion**. In this way, elements can be repurposed, edited, or deleted more easily. Rather than recording long individual lectures, record all the introductions one after the other so they are formatted and structured the same. Then record the body of each lecture. Finally, record the conclusion (which may have dates that will change). That way, every module is similar and can be re-recorded or edited as needed. You can assemble the modules into single video lectures when done.
- **Gives students multiple channels for communication.** Don't do everything in e-mails. Don't do everything in videos. Don't do everything in pod casts. Always have written documentation along with visual or auditory explanations. Test these with a screen reader, such as Bobby.
- **Gives students multiple learning approaches.** Try to combine visual, auditory, and tactile approaches. You probably cannot post three versions of every assignment, demonstration, and explanation, but don't limit your instruction to only one learning mode. An online course is more than a collection of class notes.
- **Makes it easy to communicate.** Open a free discussion area where students can communicate without a moderator (and you stay out of it). Use the mail system within the CMS (if available) or the university e-mail. Assure that links to the instructor's online chat or video conferencing name are easily available.

Conclusion

Online delivery of graphics instruction has the potential to maximize resources and reach underserved populations. It does, however, come with significant overhead—for course designers, instructors, and students. It also challenges our conception of learning styles, as students are required to exhibit a greater level of self-direction. Online has become an alternative instructional channel with its own unique strengths and weaknesses, to be considered along with accepted lecture, laboratory, and practicum models. It is not better or worse than the traditional classroom. It is different.

Using Online Catalog Part Files in Graphics and Design Courses

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Abstract

This paper will investigate the use of a catalog portal that facilitates searching for components and downloading CAD files in a wide range of standard and native file formats. The paper will suggest exercises that can be integrated in existing introductory graphics courses as well as intermediate and upper level design courses in mechanical engineering. The goal of these exercises is to familiarize students with the use of standard parts and purchased components within the design activity, and to minimize the waste of time associated with modeling of existing components. Feedback from students in a junior/senior level Advanced CAD course indicate that these exercises are useful in preparing students for using standard parts in unstructured design activities such as senior projects.

Introduction

Few entry-level engineering students are familiar with standard engineering components and purchased parts used in an industrial setting. When asked to create even simple assemblies in introductory level graphics and design courses, students will often spend vast amounts of time creating solid models of parts such as fasteners, gears, springs and other standard components. There is no need for these students to reinvent the wheel! Manufacturers have offered CAD models of their components in various formats, however, the parts may not be available in the desired native CAD formats needed, and individual manufacturers' part catalogs are difficult for students to search due to their lack of familiarity with the available components.

PARTsolutions LLC provides a portal to over 500 part catalogs with access to downloadable 3D part files in native CAD formats for all common CAD systems. With this extensive selection of part files available, students can incorporate standard purchased parts in their designs. The portal can be used to support student work in CAD or other design courses as well as capstone design projects, where students are most likely to need models of purchased components. The availability of a wide array of formats facilitates use in a university environment where a variety of CAD software is available to the students.

Design Exercise 1

PARTsolutions provides a tutorial exercise to demonstrate the functionality of the portal. The goal of the exercise is to create an engine hoist, shown in Figure 1. The hoist is comprised entirely of standard fasteners, purchased components and modified stock material.

Figure 1. Engine Hoist used for Design Exercise 1

The first phase of the design exercise utilizes a selection of square hollow cold formed steel extruded sections in various sizes. Given the standard part designation, EN10219, the student can search the Industry Standards database for the appropriate stock parts and select the desired size from a table; the native CAD files are then imported directly to the CAD assembly model, and modified to the desired dimensions with the addition of a few holes and simple cut features. Similarly, stock fasteners are selected from the listing of industry standard parts.

The second phase of the exercise addresses the use of purchased components. These include a caster assembly, chain, and hook. In this case, the desired component is found using a simple key word search, such as "caster". Note that the caster component is actually an assembly, with all of the individual parts (frame, wheel, pin, etc.). The selected caster assembly and hook are shown in Figure 2.

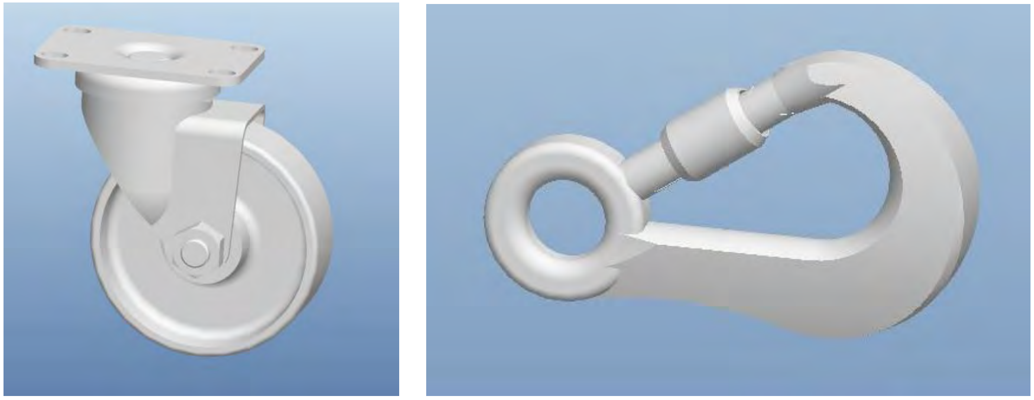

Figure 2. Caster assembly imported from vendor catalog (left) and DIN 5290-1A Hook component selected from key word search (right)

In addition to searches using text identifiers, the PARTsolutions software also includes a geometric search capability. Thus, if the general shape of an object is provided, the software can search for available parts based on geometric shapes. This is demonstrated in the tutorial exercise using the hook component. The student sketches the general shape of the hook and creates a simple extrusion, as shown in Figure 3, then invokes the geometric search function. The geosearch returns parts that match the desired shape based on three factors: 3D shape, 3D shape and 3D size. In this example, the previously selected hook scored 85%, 89% and 83% match, respectively.

Figure 3. Simple extrusion of hook used for geometric search

Results

The tutorial exercise was assigned in an Advanced CAD course for junior/senior level mechanical engineering students. Twenty-two students were enrolled in the class; all of the students had either taken the Introduction to CAD course using SolidWorks, or had experience using other solid modeling software such as Inventor through high school or internships. The course used PTC Creo Parametric software, and the exercise was completed using Pro/E Wildfire5. Upon completion of the exercise, the students were asked to complete a survey to provide feedback on their experience. Eighteen students completed the survey.

When asked, all of the students either agreed or strongly agreed that that the availability of part files from vendor catalogs serves to expedite the design process. All but two of the students felt that the design exercise improved their understanding of the procedure for using standard part files (search/insert/modify) in a design activity. One of those that responded negatively stated that he had previous experience with downloading files from a vendor website, and was therefore already familiar with the process. Sixteen of the students (89%) either agreed or strongly agreed that parts from the PARTsolutions catalog were easily integrated into the design activity in the lab exercise.

Regarding the geometric search function, all but one of the students found this feature to be useful. One student stated that the function "is really helpful if you do not know a part number, or if you don't know what a part is called"; others commented that it was quick and easy to sketch a rough shape, and that the concept was "cool".

In order to assess the students' past experience with standard part files, they were asked if they had ever created a solid model for a standard catalog part (excluding class exercises). Two thirds of the students (12/18) responded positively. Reasons given for not downloading vendor part files included: part files not available from vendor catalog (7/12), parts on vendor website not in correct format (4/12), vendor not selected (4/12), unsure how to find part files (3/12), unsure where to find vendor websites (2/12). Students also reported that featureless or "dumb" parts in generic formats such as parasolid or .step files were effective in "filling in space" in their designs, but were difficult to place in assemblies due to absence of datum planes and axes. Downloaded assembly files were sometimes under-constrained. Students also stated that they sometimes downloaded part files from sites such as 3D ContentCentral, a free website that offers user-contributed and supplier-certified part and assembly files (Dassault Systèmes, 2011). These files were sometimes found to be "sketchy", according to one student.

Conclusions

These responses indicate a variety of problems that students encounter when attempting to use purchased components and standard parts in their designs, and the value of including a structured exercise in the CAD course to allow the students to become familiar with the use of online parts. Students are not familiar with suppliers, and the ability to search through a wide selection of catalogs and standard parts is a useful function. This helps the students to become familiar with terminology used to describe parts as well, particularly through using the geosearch function. One student commented that it would have been useful to have this experience earlier in the course.

References

Dassault Systèmes. (2011). *3D ContentCentral.* Retrieved December 14, 2011 from http://www.3dcontentcentral.com/Default.aspx.

A Study to Examine the Role of Print, Web, and Social Media for Recruiting Students

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Abstract

Recruiting for higher education is a well-documented and practiced process; however, new social media venues of delivering information are changing the way some universities are reaching prospective students. Recruiting students for higher education has typically been accomplished by a variety of traditional methods, including print, Web, and campus visits. While these methods continue to be used, the existence of new social media including Twitter, Facebook, blogging, and message boards has pushed many universities towards recruiting in new ways. As we think about recruiting students into our programs, we are faced with many more choices than we have had in the past. We are also faced with students who are much more media savvy than previous students. There seems to be very little in the literature about the impact and usefulness of the newer social media outlets. This study was designed to determine how effectively students perceive different recruiting methods (print, Web, and social media) as well as who helped them sort through all of the information to make their choices. First semester freshmen in the College of Technology (CoT) at Purdue University were surveyed to determine how print, Web, and social media for recruiting are perceived by prospective students. They were asked what people influenced them during their college search and which forms of media influenced their decision-making process. This paper will present results of a Web survey conducted during fall 2010.

Introduction

Colleges spend a lot of time and money on recruiting, in an effort to attract the best students to their programs. In today's market, the challenge is even greater. For many years, marketing typically focused on printed materials and on-campus activities. Although these venues are still valid, the Web has expanded the ease and scope of promoting colleges online. Much of the printed material has been duplicated or expanded to the Web. Another resource has been added with the onset of social media. Social media can be defined as "a group of internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content (Kaplan & Haenlein, 2010)." Facebook and Twitter are two of the most prevalent social media outlets.

Social media presents another opportunity for recruiting. The College of Technology at Purdue has recently started to explore the use of social media as a resource. In order to better understand how students were accessing recruiting information about the college, a study was designed to poll the incoming freshmen about what materials they used most in making their decision to enroll in Purdue's College of Technology. The objective of the study was to determine the most successful venues for recruiting students and the prevalence of social media usage among the freshmen.

Current Recruiting Methods

Face-to-face

The College of Technology employed a variety of recruiting methods to recruit students into the fall 2010 class. The University has an expansive schedule of recruiting days for high school students who have not yet applied and other days for those who have already been admitted. The College of Technology participates in these face-to-face opportunities with a presentation about the college and tours of the college facilities.

In addition to the campus visits, College of Technology student services representatives visit a large number of Indiana high school *Project Lead the Way* classes. The representatives promote the college programs, network with the teachers, and discuss the need for high school mathematics and science.

Admitted female, underrepresented, and high achieving students received at least one phone call from a current student. The purpose of the phone calls was to make contact, inform, answer questions, and encourage the prospective student to commit for the fall.

Print

The college has a variety of print publications; however, the major print recruiting piece is the *College of Technology* magazine. This annual publication is targeted towards high school students and their parents. It includes information about all of the technology programs as well as information about scholarships, student organizations, and vignettes of current students. Programs are grouped into four major areas rather than by individual majors: 1) computing, 2) engineering technology, 3) technology management, and 4) professional programs. In this manner, a student who was interested in computing would see all of the programs related to computing, a student who was interested in engineering technology would find all of those programs in the same place.

Web

The College of Technology has had a Web site for a long time. For this recruiting class, the Web was organized similar to the print magazine. All of the programs were grouped into the same four areas that were used in the print magazine. Included on the Web site, with each of the four program areas, was a video which explained more about the different majors and opportunities for students and graduates.

Social Media

While recruiting for the fall 2010 class, the college did have a Facebook page and a Twitter presence; however, the college did not have an in-depth strategy for embedding these into the recruiting process.

Methodology

A survey was devised to determine what recruiting materials were typically used by prospective students that selected the College of Technology at Purdue University. The intention was to gather their preferences and thoughts as to their choice of recruiting material formats. It was hoped that a comparison could be made of the effectiveness of each medium in order to impact future marketing strategies. Two of the questions the study hoped to answer were: 1) How did students choose Purdue's College of Technology; and 2) What aspects of the various recruiting media attracted them to the College of Technology?

The Survey

The survey was developed through Qualtrics, an online survey development package. The survey used a combination of multiple-choice questions, a Likert Scale format, and open-ended questions. The survey took approximately ten minutes to complete and was e-mailed directly to the first year students in the college.

When designing a survey, the researcher needs to avoid leading questions, present questions in a balanced manner, and not create questions with an argument or counterargument already within the question (Scheaffer, et al., 2011). The initial survey was developed by Computer Graphics Technology graduate student, Brandon Karcher, as part of his thesis. Initially, a pilot survey was created and tested to identify any misleading questions or omissions. It was tested on a sample group as part of a technology class in fall 2010. The pilot resulted in minor changes related to format. Some of the questions were changed from open-ended to a list of possible choices including "other" to allow for additional comments. This change was made in order to ensure that the students would better understand what information was being sought.

The survey was modeled on the Theory of Planned Behavior that was proposed and developed by Icek Ajzen in his paper, *From Intentions to Actions: A Theory of Planned Behavior* (1985). According to the theory, decisions are guided by three considerations: behavioral, control, and normative beliefs. When these three beliefs combine, an intention is formed. The intention is then linked to a behavior, and depending on the perceived behavioral control an individual has, the behavior will be carried out. According to the theory, in order to make a decision, a person takes into consideration his/her perceived beliefs and attitudes, then develops an intention, and finally a behavior follows. To follow this model, questions are asked in a manner that allows for questions based on attitudes/beliefs, intentions to use various media, and finally questions regarding behaviors (Fishbein & Ajzen, 2010).

To utilize the Theory of Planned Behavior, the survey posed questions in a manner that flowed chronologically, as well as in the same order of the theory. First, questions were asked about the students' experiences while enrolling in the College of Technology. Questions such as "Who or what influenced you the most in making the decision to attend the College of Technology (CoT)?" were used to gather information regarding the student beliefs and/or attitudes regarding different factors about parents, advisers, and mediums such as print or Web. Next, according to the theory, the intention or readiness to perform a behavior needed to be assessed (Fishbein & Ajzen, 2010). The survey covered multiple areas related to intention. Measuring students' willingness to consider social media, and their intention to later use it as an information source, compares to the intention step in the Theory of Planned Behavior. Finally, the behavior section focused on how the students used, are currently using, and how they think the College of Technology *could* use media to recruit students. (Karcher, 2011)

Sample Population

The population chosen for the study was the freshman class that entered the College of Technology at Purdue University in fall 2010. Only first-year students (freshmen) were included; students who had transferred into the program from another major or another university were not included in the study. The first-year student group was chosen because these students had most recently used the College of Technology recruiting materials during their search for a college to attend.

The fall 2010 freshman class of the College of Technology consisted of 563 students – 83.6 percent were male and 16.4 percent were female. Participation in the survey was voluntary, and the subjects were not identifiable to the researchers. The survey was e-mailed directly to the students and results were recorded through Qualtrics. Of the 563 subjects that received the survey, 57 responded for a total of approximately 10 percent. Of the respondents, 81 percent were male and 19 percent female. During fall 2010, there were 3,450 students in the College of Technology of which 86.3 percent were male and 13.7 percent were female (*Purdue Data Digest, 2011*). The percentage of females who responded is slightly higher than the percentage of females in the freshman class or in the college as a whole; however, the participants were relatively representative of the entire College of Technology undergraduate student body. Most of the respondents were residents of Indiana, 65 percent, with only 35 percent out-of-state respondents.

Results of the Study

The purpose of this study was to gain insights into the question—"What role does print, Web, and social media play in recruiting for higher education?" The survey supplied information related to: 1) what attitudes students have regarding the different types of media used for recruiting; 2) which methods students used in searching for a potential university, and what were their experiences with those mediums; and 3) what other factors affected the recruitment process for potential students.

The first set of questions, relating to attitudes and beliefs, was introduced as follows—*Think back to when you were trying to select a college and answer the following questions.* Table 1 shows how the prospective student first found out about the College of Technology. Where did they start their Purdue search? Did they know about the College of Technology prior to starting their search? As indicated by the results, 37 percent of the prospective students started their search at the Purdue Web site. None of the students indicated that they started at the College of Technology Web site. This might suggest that the college could do a better job marketing to prospective students and their parents.

Media Type	Responses	Percentage
Purdue Web site	19	37.0%
High School Adviser	8	15.0%
Parents	8	15.0%
Other	6	12.0%
Friends & Relatives	5	10.0%
CoT Promotional Material	5	10.0%
CoT Event	1	2.0%
CoT Facebook	0	0.0%
CoT Twitter	0	0.0%
CoT Web site	0	0.0%

Table 1. How did you first hear about the College of Technology?

Table 2 shows the primary information sources prospective students used after they became aware of the College of Technology Web site. The College of Technology Web site is indicated in the top three choices for 56 percent of the students. This reinforces the value of the information provided on the College of Technology Web site.

Media Type	Responses	Percentage
Purdue Web site	40	77.0%
CoT Web site	29	56.0%
CoT Promotional Material	16	31.0%
Parents	14	27.0%
High School Advisor	13	25.0%
CoT Event	9	17.0%
Friends & Relatives	8	15.0%
Other	7	13.0%
CoT Facebook	1	2.0%
CoT Twitter	0	0.0%

Table 2. When you were researching the College of Technology, what were your primary information sources? Choose top 3.

The last question in this set asks the prospective student to indicate what most influenced them to enroll in the College of Technology. Table 3 shows the most important factors that influenced their decision.

Media Type	Responses	Percentage
Parents	31	60.0%
Purdue Web site	23	44.0%
CoT Web site	18	35.0%
Friends and Relatives	14	27.0%
High School Advisor	12	23.0%
CoT Promotional Material	12	23.0%
Other	12	23.0%
CoT Event	7	13.0%
CoT Facebook	0	0.0%
CoT Twitter	0	0.0%

Table 3. Who or what influenced you the most in making the decision to attend the College of Technology? Choose top 3.

Note that throughout the first set of questions, Facebook was only indicated once and Twitter not at all. None of the prospective students indicated that they searched in these areas.

The second set of questions (loosely related to intentions) was introduced as follows—*Indicate your Internet usage and habits when you were a high school student.* This portion of the survey determined the typical Internet and social media usage of students while in high school. Figure 1 shows the amount of time high school students spent daily at various online tasks.

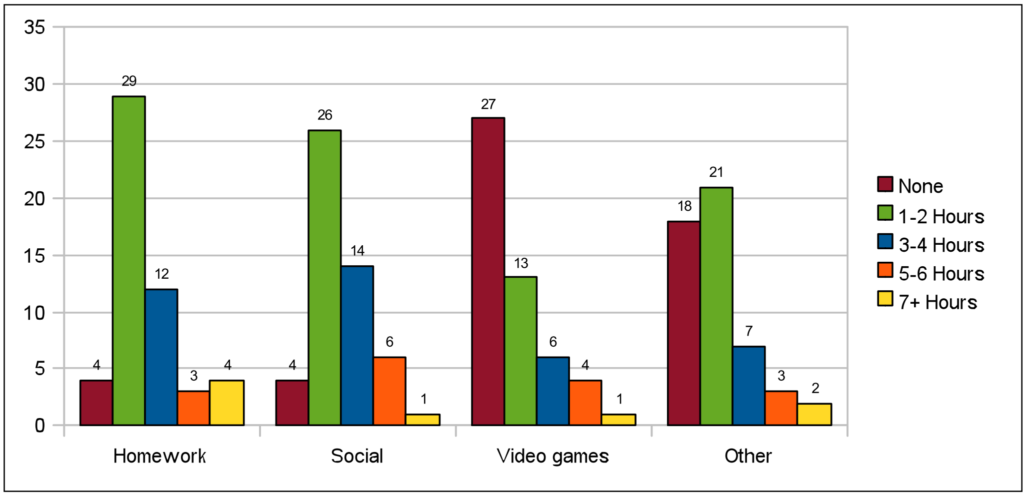

Figure 1. How much time per day did you spend on the Internet?

The two most prominent uses were for homework and socializing, with students typically spending one to two hours a night on these activities.

Figure 2 shows the number of times the prospective student accessed the College of Technology Web site when searching for information. Most of the respondents indicated that they accessed the Web site two to five times in the course of their search. An additional question asked—*Did your parent(s) or guardians(s) assist you in your search for a college?* —To which 77 percent responded "yes." When asked to indicate all of the methods they used to search, the replies indicated that it was predominantly the Internet (82%), followed by campus visits (72%), and printed materials (67%).

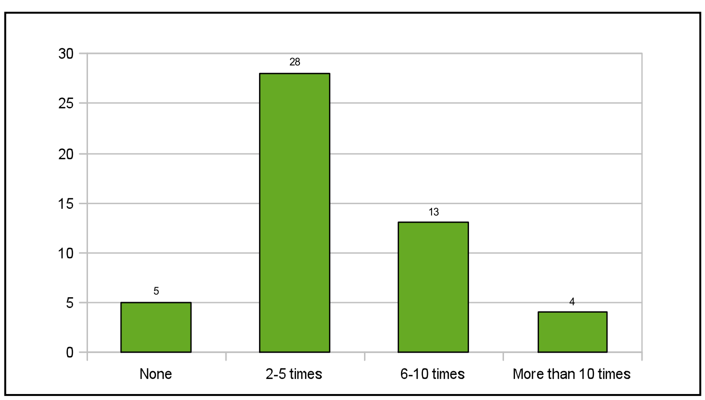

Figure 2. How many times did you visit the College of Technology Web site as part of your college search?

Figure 3 shows what social media responders were using at the time of their college search. Facebook was the overwhelming response with Twitter a distant second. In addition, they were asked if they used social media in their college search. The majority, 58 percent, indicated that they did not use social media in their college search. Of the remaining respondents that did use social media in their search, 18 percent found it very useful, 50 percent found it moderately useful, and 32 percent found it somewhat useful. When asked if they found useful information through a social network, 84 percent responded that they used Facebook, with only 11 percent using Twitter.

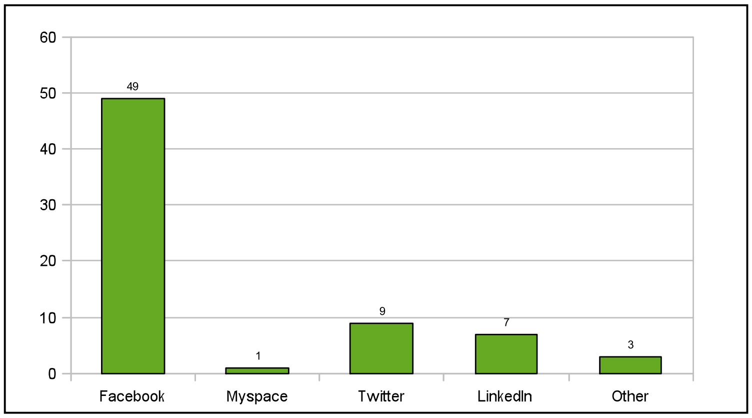

Figure 3. What major social media do you currently use?

Respondents were also asked if they knew that the College of Technology had a Facebook and Twitter presence and if so how did they find it. In response, 48 percent answered that they were aware of the College of Technology Facebook and Twitter accounts. When asked how they learned about Facebook and Twitter, the responses were varied and included random searches, from a friend, and the College of Technology Web site.

The last set of questions (related to behaviors) was introduced as follows—*The following questions will have you evaluate the recruiting material.* First, the prospective students were asked to evaluate the media used by the College of Technology and how it compared to other colleges they were researching. Second, they were asked which mediums were most helpful in their search. Overall, the College of Technology materials were shown to be effective in all four areas: visual appeal, informative, persuasive, and availability. The majority ranked the materials as a three or a four on the Likert scale.

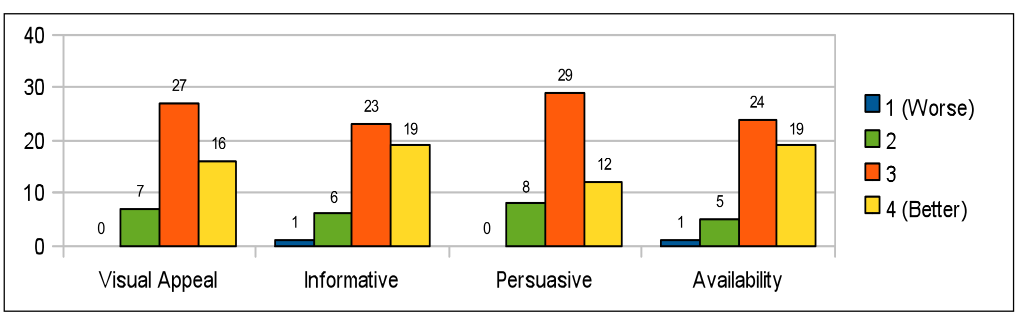

Figure 4. How did the College of Technology compare with other colleges?

Another question asked respondents to rank the usefulness of various media types used by the College of Technology. The top three choices were the College of Technology Web site, with the College of Technology promotional material and events next and relatively closely weighted. By comparison, Facebook and Twitter were the two lowest percentages.

Media Type	**Not Beneficial**	**1**	**2**	**3**	**4**	**Extremely Beneficial**	**Percent > 4**
CoT Event	5	2	12	9	9	9	**39%**
CoT Facebook	11	10	5	11	7	2	20%
CoT Promotional Material	3	3	6	16	8	12	**42%**
CoT Twitter	26	9	2	4	4	1	11%
CoT Web site	1	2	2	13	15	16	**63%**

Table 4. Of the following College of Technology information sources, which ones did you find the most beneficial?

The final question asked what medium they think the College of Technology should use in the future for recruiting purposes. Table 5 shows the results. Facebook was ranked the highest at 29 percent. However, College of Technology events and the Web site followed closely with 24 percent each. College of Technology printed promotional materials came in at 16 percent, with Twitter receiving only 4 percent. It is interesting to note that these students who ranked Facebook slightly higher than events or promotional (print) materials, did not consider Facebook an important aspect of their search process which they had undertaken only months earlier.

Answer	**Responses**	**Percentage**
CoT Event	**12**	**24%**
CoT Facebook	**15**	**29%**
CoT Promotional Material (print)	8	**16%**
CoT Twitter	2	4%
CoT Web site	**12**	**24%**
Other	2	4%

Table 5. How do you think the College of Technology should connect with current high school students?

Conclusions

The study was designed to look at three questions. The respondents to this survey were first-year freshmen in the College of Technology during fall 2010. A summation of their responses follows.

What attitudes students have regarding the different types of media used for recruiting:

- During high school, most students used the Internet mostly for homework and socializing.
- Most of the students were active on Facebook; however, they did not use the Purdue Facebook page during their search.
- Facebook was recommended as the medium to use to connect with future students.
- College of Technology events and the College of Technology Web site were also recommended for connecting with future students.

What methods did students use in searching for a potential university?

- Most of these students first connected with the college through the Purdue University Web site.
- During their search, the College of Technology Web site was considered an important source for information followed by College of Technology events and College of Technology promotional materials.

What other factors affected the recruitment process for potential students?

- Parents had the strongest influence on helping students make their final college decision.
- The Purdue and College of Technology Web sites were also strong influencers.

Although a small sample, this study gave some insights into how students searched for a college, who/what influenced them during their search, and their perceptions of what media they think the college should use in future recruiting. A follow-up survey with fall 2011 freshmen will give additional data and insight into these issues.

References

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), *Action-control: From cognition to behavior* (pp. 11-39). Heidelberg: Springer.

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach.* New York: Psychology Press.

Kaplan A., Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Business Horizons,* 53(1), 59-68. doi:10.1016/j.bushor.2009.09.003.

Karcher, B. (2011). Recruiting for higher education: The roles that print, web, and social media play in the decision process for prospective students. (Unpublished masters thesis). Purdue University. West Lafayette, IN.

Purdue Data Digest. (2011). *College of Technology, Enrollment by Gender.* http://www.purdue.edu/datadigest/students/school/tech/stu_gender.pdf.

Scheaffer, R., Mendenhall, W., Ott, L., & Gerow, K. (2011). *Elementary Survey Sampling* (Seventh edition). Boston: Brooks/Cole.

Engineering Graphics Literacy: Measuring Students' Ability to Model Objects from Assembly Drawing Information

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Abstract

During the Spring 2011 semester, an engineering graphics literacy assessment was developed by a visiting Fulbright Scholar. The assessment was administered in a junior-level constraint-based modeling course. Twenty-nine students were asked to model seven parts given in an assembly drawing of a device within a 110 minute class period. The parts in the assembly ranged in complexity from a ball to a valve body. Students were given a ruler to measure parts on the B-size drawing and determine sizes of features based on the given scale (2:1). There was a positive relationship between the scores on the activity and the pace at which each student completed the parts. Only eight students modeled all seven parts in the assembly. There were significant correlations between the scores on the modeling assessment and other measures in the course (final project, final exam, and final course average). This paper summarizes how students performed on the assessment (number of parts correctly modeled, scores, total time, etc.), reports analyses of relationships between their scores on the assessment and other measures in the course, and also presents ideas for future studies.

Introduction

Over the last 30 years engineering graphics content in engineering programs has changed to meet the needs of industry and also to meet changing accreditation requirements. As the number of required engineering graphics courses has been reduced, programs have made decisions about what to keep in their curricula. Solid modeling and other CAD tools have replaced descriptive geometry and other engineering graphics topics. This "computerization" within engineering programs has been necessary to provide students with current skills, but has it come at the cost of deficiencies in other areas (Livshits & Sandler, 1999).

Engineers and technicians are still required to read and interpret engineering drawings as part of their daily tasks. These drawings remain one of the primary pieces of legal documentation for product development. They also are the main tool for communication between design, manufacturing and quality control. Traditional engineering graphics education appears to still be an important topic of conversation around the world. Even when CAD instruction is the main focus of many courses, faculty still have a variety of views about what is important when preparing students adequately for careers in engineering and design (Dobelis, Veide, & Leja, 2008; Kise, Sekiguchi, Okusaka, & Hirano, 2008; Kondo, 2008; Kotarska-Bozena, 2008; Suzuki & Schroecker, 2008; Szilvási-Nagy, 2008; Han, Zhang, Luo, & Luo, 2010; Hu, Wang, Shu, Wang, & Dai, 2010; Jurane, 2010; Meng, Li, Li, Zhu, & Pan, 2010; Tong & Han, 2010; Wang & Guo, 2010; and Wang & Hao, 2010).

Since the number of required engineering graphics courses in post-secondary engineering programs varies greatly in the United States (Branoff, 2007; Meyers, 2000) and content has shifted from standards and conventions toward teaching software (Clark & Scales, 2000), are students still able to successfully read and interpret engineering drawings?

The primary research question for this study is, "how well do current engineering and technology students read engineering drawings?" Specifically, can students take the information given on an assembly drawing, visualize or interpret each part, and then create 3D models of the parts in a constraint-based CAD system?

Participants

Twenty-nine students enrolled in a second level engineering graphics course participated in the pilot study. The course consists of engineering graphics standards and conventional practices (sectional views, dimensioning, threads & fasteners, and working drawings), geometric dimensioning and tolerancing, and constraint-based modeling techniques (assemblies, advanced drawing applications, macros, design tables, and rendering). Tables 1-3 summarize demographic information on the participants.

Table 1. Gender of Participants.

Gender	Frequency	Percent
Female	5	17.24%
Male	24	82.76%
TOTAL	29	100.00%

Table 2. Academic Year of Participants.

Year	Frequency	Percent
Freshmen	0	0.00%
Sophomore	2	6.90%
Junior	9	31.03%
Senior	18	62.07%
TOTAL	29	100.00%

Table 3. Academic Major of Participants.

Major	Frequency	Percent
Biomedical Engineering	1	3.45%
Business Administration	1	3.45%
Civil Engineering	1	3.45%
Computer Science	1	3.45%
Mechanical and/or Aerospace Engineering	13	44.83%
Nuclear Engineering	1	3.45%
Technology Education	8	27.59%
Textile Engineering	3	10.34%
TOTAL	29	100.00%

Most of the students in the course were male from either engineering or technology education. Technology Education students take the course as part of their major requirements, while other students typically take the course as part of a 5 course minor in Graphic Communications.

Instrument

To answer these questions, drawings were developed to assess students' ability to "read" or understand information. Ten mechanical devices with different levels of difficulty consisting from 6-11 parts were modeled. A wide range of elements such as threads, chamfers, fillets, grooves, and slots were present. Several devices also included springs. From the computer models a multi-view assembly drawing with parts list was created and was used for practical training and pilot testing purposes. Figure 1 shows an example of one of the assembly drawings.

Two of the assembly drawings were selected for this pilot study. The metric system was used in both assembly drawings. Both assemblies were created with a drawing scale of 2:1. Only overall dimensions and a few other dimensions required for installation were given, including thread designations and sizes. All of the information about the form and size of the parts had to be determined from the given views and sections and scaled with the use of a metric ruler. Integer millimeters for nominal dimensions were required for accuracy, and no fits, tolerances or surface finishes were required to be considered in the models. To measure the students' understanding of the assembly drawing, students were required to model the individual parts using 3D solid modeling software.

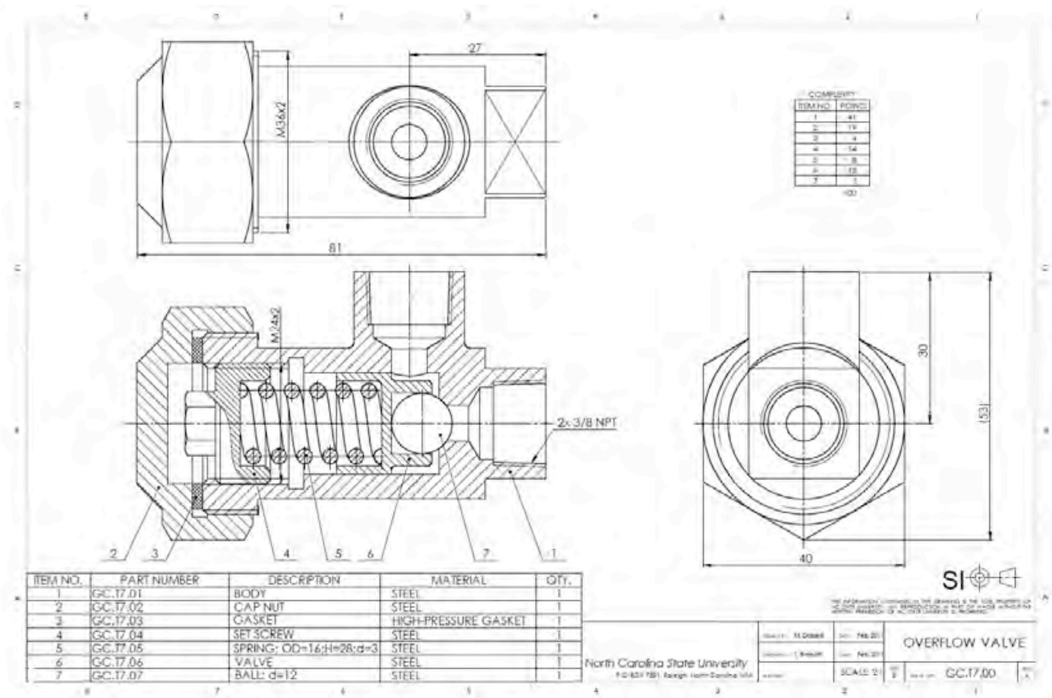

Figure 1. Example of Assessment Drawing.

Methodology

During the tenth week of classes, students were given a 15 minute lecture on how to read SI drawings that contain standards typically seen in Europe. The instructor also presented specific information on how to read one of the assembly drawings, and students were shown examples of modeling strategies on a few parts. After the lecture, students were given approximately 80 minutes to model as many of the parts in the assembly as possible (pretest). Each student was given a metric ruler so they could scale necessary dimensions from the drawing. All parts were then saved to a server space which the researchers could access. During the thirteenth week of classes, students were given a different assembly drawing and were asked to model as many of the parts as possible during a 110 minute class period (test). Again, parts were saved to a server space for the researchers to access for evaluation.

After all data was collected, one of the researchers evaluated each student's parts from the pretest and final test based on rubrics for each assembly. The assemblies were analyzed with respect to their complexity. Several factors were considered like number of geometric elements and modeling features, number of threaded elements, and total number of dimensions. Finally, the complexity of the part in each assembly drawing was characterized by the number of dimensions required for the modeling of that particular part. This means that the dimensions accounted for the size and location of geometric primitives from which the part was built. The complexity of each part was determined as a ratio of number of dimensions for that part and total number of dimensions in the assembly, normalized against 100. Table 4 displays the data for the final modeling assessment in the study. Figure 2 shows the individuals parts for the assembly.

Table 4. Complexity of Parts in the OVERFLOW VALVE Assembly.

Item No.	Geom	Feat	Dim	Thread	Time	Complexity
1	5	15	30	4	39	41
2	3	10	14	1	11	19
3	2	2	3	0	1	4
4	3	7	10	1	6	14
5	3	8	6	0	22	8
6	3	4	11	0	6	13
7	3	10	1	1	11	1
Total	**22**	**56**	**75**	**7**	**96**	**100**

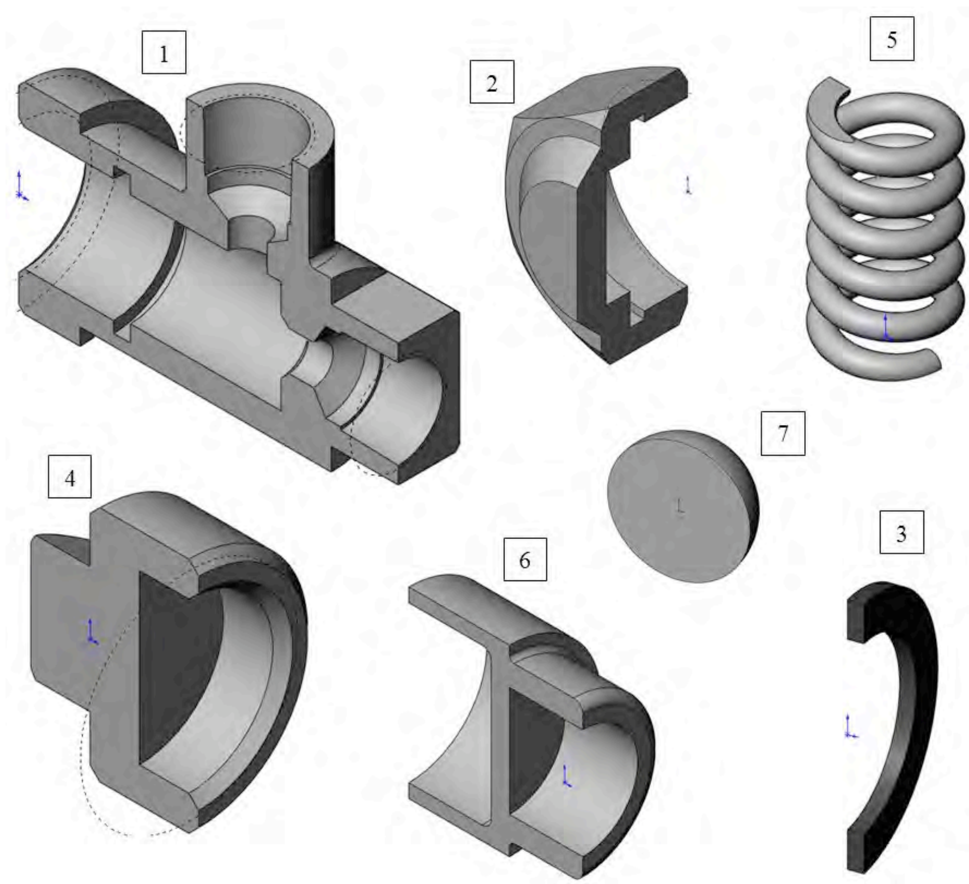

Figure 2. OVERFLOW VALVE Parts.

Also evaluated was the time students took to model each of the parts. The time stamps for features and sketches in the model file database were examined to determine when each item was created and last modified. Time t_1 was when the first feature's sketch was created and was assumed as a time when the student started to create the model. The latest time when any feature in the design tree was modified was assumed as the modeling end time t_n (Figure 3). The total time t required for part modeling was calculated as $t = t_n - t_1$.

Design tree	Data created	Last modified	Recorded time convention
Origin			
Revolve1	8:44:45	8:44:45	
Sketch1	8:41:53	8:44:38	<- 1st sketch creation time t_1
Cosmetic Thread1	8:46:37	8:46:37	
Chamfer1	8:45:31	8:45:31	<- 2nd feature's creation time t_2
Boss-Extrude1	8:49:25	8:49:25	
Sketch2	8:47:33	8:48:59	<- 3rd feature's creation time t_3
Cut-Extrude1	8:49:57	8:49:57	<- last feature's last modification time t_n
Sketch3	8:49:28	8:49:28	<- 4^{th} (last) feature's creation time t_4

Figure 3. Example of an Analysis of a Design Tree.

The Assessment Rubric

The assessment rubric spreadsheet was created to account for model accuracy and time required to model each part. Each feature and sketch (if any) was analyzed individually, and a penalty point was assigned for each wrong geometric dimension including under-defined sketches. Penalty points were added for each dimension of the geometric primitive missing in the model, incorrect dimensions, and failure to correctly represent cosmetic threads.

Analysis of Results

Student scores on the final test were grouped by performance. Table 5 displays test scores for each of the performance groups.

Table 5. Performance of Students on the Final Test.

Performance group	Test score	N	Percentage
1	0 – 20	4	13.8
2	20 – 40	6	20.7
3	40 – 60	7	24.1
4	60 – 80	6	20.7
5	80 – 100	6	20.7
	Total	**29**	**100**

The pace at which students modeled parts appears to be related to the score obtained on the test. For this study it resulted in a statistically significant positive linear regression equation. Figure 4 shows the results of students' scores by the time required to complete the test.

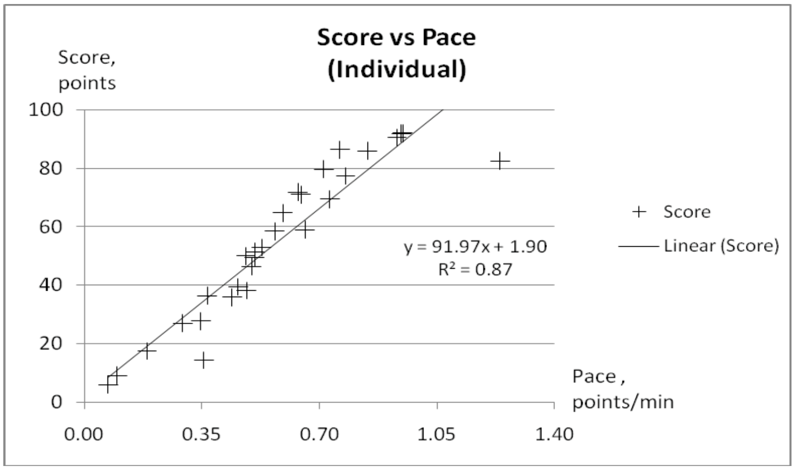

Figure 4. Test Score vs. Pace.

To get a better understanding of student performance, groupings were made by the number of parts completed during the 110 minute class period. These results are displayed in Table 6.

Table 6. Average Score and Time by Number of Parts Modeled.

Number of parts modeled	Number of students	Average score in group	Average time used, min	Average pace, points/min
7	8	84.0	99.6	0.87
6	7	60.2	101.5	0.59
5	3	57.4	90.3	0.63
4	3	28.9	92.2	0.31
3	4	35.4	81.7	0.42
2	2	27.8	86.3	0.34
1	2	16.5	87.2	0.18

Students who only modeled 1-3 parts spent less time modeling than students who modeled more parts. Students who modeled more parts during the class period also tended to model their parts more correctly than those who modeled fewer parts.

Students' scores on the modeling test were also compared to three other measures in the course – final project grade, final exam grade, and final average in the course. Figures 5-7 display the scatterplots for these data. Table 7 shows the descriptive statistics for the test and other measures in the course.

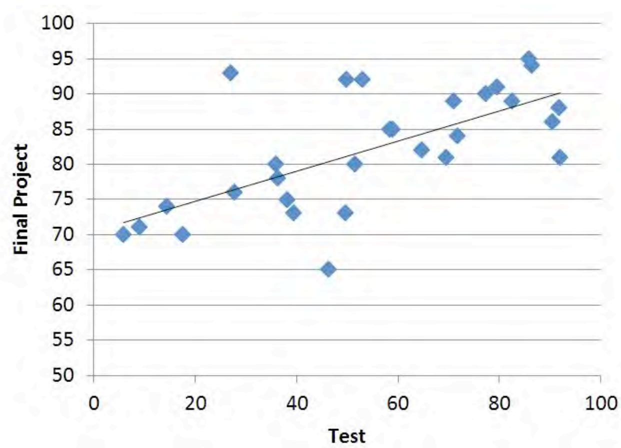

Figure 5. Students' Test Scores vs. Final Project Grade.

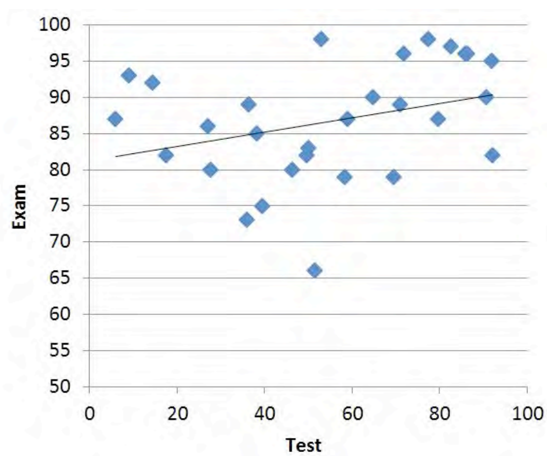

Figure 6. Students' Test Scores vs. Final Exam Grade.

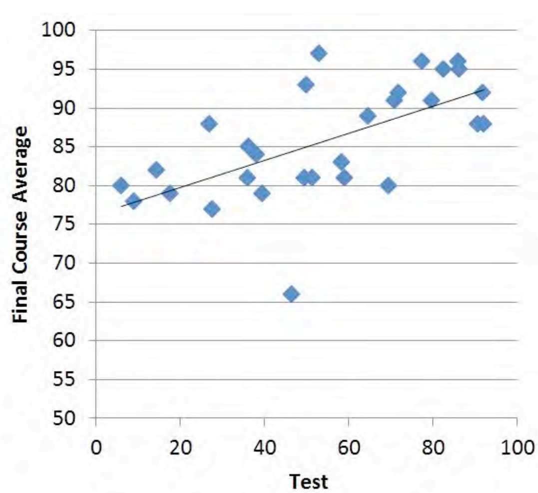

Figure 7. Students' Test Scores vs. Final Average in Course.

Table 7. Descriptive Statistics.

	N	Range	Min	Max	Mean		Std. Dev	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Err.	Statistic	Statistic
Test	29	86.12	5.91	92.02	54.56	4.86	26.15	683.90
Project	29	30.00	65.00	95.00	82.14	1.564	8.421	70.90
Exam	29	32.00	66.00	98.00	86.62	1.503	8.095	65.53
Final Ave	29	31.00	66.00	97.00	85.79	1.368	7.365	54.24

To determine if a relationship exists between the modeling test and students' project grade, exam grade, and final average in the course, Spearman's rho analyses were conducted. Tables 8-10 display the results of these analyses.

Table 8. Spearman's Rho Correlation – Test by Final Project.

Spearman's rho		Test	Final Project
Test	Correlation Coefficient	1.000	.644**
	Sig. (2-tailed)	.	.000
	N	29	29
Final Project	Correlation Coefficient	.644**	1.000
	Sig. (2-tailed)	.000	.
	N	29	29

**. Correlation is significant at the 0.01 level (2-tailed).

Table 9. Spearman's Rho Correlation – Test by Exam.

Spearman's rho		Test	Exam
Test	Correlation Coefficient	1.000	.374*
	Sig. (2-tailed)	.	.046
	N	29	29
Exam	Correlation Coefficient	.374*	1.000
	Sig. (2-tailed)	.046	.
	N	29	29

*. Correlation is significant at the 0.05 level (2-tailed).

Table 10. Spearman's Rho Correlation – Test by Final Average.

Spearman's rho		Test	Final Ave
Test	Correlation Coefficient	1.000	.661**
	Sig. (2-tailed)	.	.000
	N	29	29
Final Ave	Correlation Coefficient	.661**	1.000
	Sig. (2-tailed)	.000	.
	N	29	29

**. Correlation is significant at the 0.01 level (2-tailed).

For each of the variables (final project, exam, and final average) a significant correlation was found with students' scores on the modeling assessment.

Conclusions

Several conclusions can be drawn after analyzing the data from the Spring 2011 semester. First, there is a significant correlation between students' scores on the modeling assessment and students' scores on the final project, final exam, and final average in the course. Although the scatterplots revealed that scores on the modeling assessment cannot accurately predict a student's score on the other measures, in general, students who scored higher on the assessment tended to score higher on the final project, final exam, and in the course.

Another conclusion that can be drawn from the data is that students who accurately modeled all of the parts in the assembly appeared to make use of the class time much more efficiently than students who only modeled 3 or fewer parts. Based on the time-stamp data from the model files, students who modeled only a few parts did not appear to have worked consistently in the software. It is not known whether they were spending time struggling with how to begin a modeling task or whether they elected to do nothing for long periods of time.

It is necessary to talk about the scale-up possibilities of this type of assessment for measuring engineering graphics literacy. Although the rubric used to evaluate students' models delivered accurate results, the time required to evaluate each student's models may prevent some faculty from administering the assessment. The researchers plan to look at alternative methods for accurate measuring success on the modeling assessment.

Finally, there was a wide range of scores on the modeling assessment (5.91-92.02), which indicates that not all students were able to successfully "read" the engineering drawing. It is not known whether this was a result of students not being able to visualize the individual parts within the context of an assembly or whether students just did not take the task seriously. Since this was one of the main research questions for the study, more investigation is needed to determine why some students were not able to successfully model the parts. This may involve qualitative techniques such as observations during the modeling process and interviews after the assessment.

Future Research

This pilot study revealed several promising conclusions about the usefulness of the modeling assessment to determine engineering graphics literacy. Future studies will include:

- Repeating this study at other institutions in the United States and Europe.
- Examining the relationship between scores on the modeling assessment and scores on standard measures of spatial ability.
- Conducting qualitative measures to get a deeper understanding of why some students could not successfully model the parts in the assemblies.
- Examining possible ways to reduce the amount of time necessary to accurately evaluate students' models.

References

Branoff, T. J. (2007). The state of engineering design graphics in the United States*, Proceedings of the 40th Anniversary Conference of the Japan Society for Graphic Science*, Tokyo, Japan, May 12-13, 2007. (pp. 1-8).

Clark, A. C., & Scales, A. Y. (2000). A study of current trends and issues related to technical/engineering design graphics. *Engineering Design Graphics Journal, 64*(1), 24-34.

Dobelis, M. Veide, G., & Leja, E. (2008). Development of spatial imagination abilities in mechanical engineering students. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 8 pages. ISBN: 978-3-86780-042-6.

Han, B., Zhang, H., Luo, X., & Luo, Q. (2010). Engineering graphics education and modern engineering design in China. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 4 pages. ISBN: 978-4-9900967-1-7.

Hu, Q., Wang, L., Shu, H., Wang, X., & Dai, H. (2010). Study of virtual teaching environment on mechanical graphics. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 7 pages. ISBN: 978-4-9900967-1-7.

Jurnae, I. (2010). Educational aids in graphical education. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 7 pages. ISBN: 978-4-9900967-1-7.

Kise S., Sekiguchi S., Okusaka K.,& Hirano S. (2008). Training on three-dimensional computer-aided design for new employees of machine design department and its evaluation. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 7 pages. ISBN: 978-3-86780-042-6.

Kondo, K. (2008). Interactive geometric modeling using freehand sketches. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 10 pages. ISBN: 978-3-86780-042-6.

Kotarska-Bozena L. (2008). Descriptive geometry and 2D-CAD in context of modeling software in higher semesters at the civil and environmental engineering faculty. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 5 pages. ISBN: 978-3-86780-042-6.

Livshits, V., & Sandler, B. Z. (1999). Upstairs/downstairs in technical education: The unsettling effects of computerization, *International Journal of Technology and Design Education, 9*, 73-84.

Meng, X., Li, S., Li, J., Zhu, Y., & Pan, Z. (2010). The orthographic projection analysis of geometrical elements on a cuboid. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 4 pages. ISBN: 978-4-9900967-1-7.

Meyers, F. D. (2000). First year engineering graphics curricula in major engineering colleges. *Engineering Design Graphics Journal, 64*(2), 23-28.

Suzuki K., & Schroecker H. P. (2008). Application of descriptive geometry procedures in solving spatial problems with feature and parametric modelling 3D-CAD. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 8 pages. ISBN: 978-3-86780-042-6.

Szilvási-Nagy, M. (2008). What kind of geometry engineers need? *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 5 pages. ISBN: 978-3-86780-042-6.

Tong, B., & Han, B. (2010). Discussion of the cognition to two disciplines of graphics and engineering graphics. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 6 pages. ISBN: 978-4-9900967-1-7.

Wang, L., & Guo, Y. (2010). How to determine the optimum representation plan in engineering graphics. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 5 pages. ISBN: 978-4-9900967-1-7.

Wang, J. & Hao, Y. (2010). Teaching reform and practice in engineering drawing based on 3D modeling with computer. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 7 pages. ISBN: 978-4-9900967-1-7.

2D Traditional Techniques with 3D Graphics Visualization

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Abstract

A root-level understanding of foundation-level design and graphics is vital to one's ability to apply simple, stable, constructs towards resolving complex design and engineering based challenges. One's ability to know and be able to apply traditional methods is a measurable, tangible way to learn and gateway towards understanding many automated functions in today's modern computational programmed visualization sequences.

By teaching traditional techniques and applying digital methods to create their digital visualization counterparts students will better know how computational programmed sequences illustrate today's modern computer graphics. These fundamental understandings also provide teachers with ways to provide students with a solid foundation to develop and support thinking, problem-solving, and creative activity in two and three dimensions.

Introduction

This paper summarizes a way to teach students traditional engineering graphics technical illustration techniques using digital visualization software technologies. In the presentation, a traditional design graphic technical illustration technique is recreated as a Digital Visualization Method (DVM). The combined, paralleled, and summarized 2D technical illustration techniques and 3D digital visualization method is summarized in this paper. The idea of this learning unit it that by combining traditional 2D techniques with digital 3D visualization methods, students effectively learn three sets of learning objectives simultaneously (traditional technique knowledge + digital principle knowledge + digital application practice).

The synergistic result of this three-part unit is thought to provide students with higher level understandings that foster students ability to: think with traditional techniques, know foundational-level principles of visualization, and the ability to apply computational skill with digital methods to create simple, stable visualization constructs using digital visualization tools. As a result of completing these integrated techniques and methods, students will know traditional design techniques, their digital visualization method counterparts and creative applied practices.

2D Measured Perspective

The initial step in this digital method is to decide whether a one point (1pt.) parallel, two point (2pt) perpendicular, or two point (2pt.) angular perspective view is desired. Here, a perpendicular perspective is illustrated. In Fig. 1) Digital Perspective Render a 2D technical illustration Measured Plan Projection Perspective technique and an angled difference to conventional 3D digital modeling methods is shown. Like technical plan projection techniques, the figure shows a cubes data lines in a top orthographic view rotated 45 degrees in the green Y axis.

The 45 degree rotation of the cube is atypical to digital modeling. However, in this example the cube's leading edge is positioned at the 3D world space origin (0,0,0). The red X axis line and plane serves as both our theoretical perspective horizon line (HL) and picture plane PP correspondingly. A Front Perspective Camera (FPC) is initially created at the origin and later moved to SP. For simplicity, in this example, the front perspective camera @ SP is not in the third perspective, as it's digital eye is at eye level with the X axis and perpedicualr to the X plane. The camera plane is known in technical illustration as the Eye Level (EL) or Horizon Plane (HP). With the FPC camera facing along the Z axis, and looking directly at the world space origin (0,0,0) the perspective look-at point known technically as the Center of Vision (CV) and called in Maya the Center of Interest (CI) is set at the center.

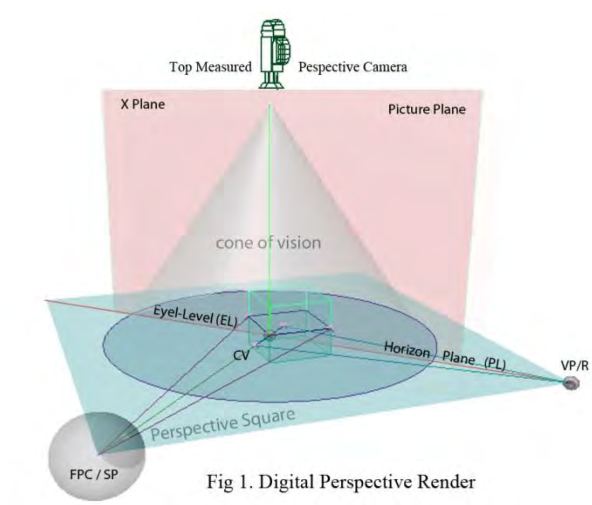

Fig 1. Digital Perspective Render

In this method, and in Fig 1) both the viewing distance and the position of both the left (L) and right (R) vanishing points (VP) can be established by placing measured square lines or a polygon plane, named Perspective Square (PS) in the scene. To create a parallel perspective, the Perspective Square is centered @ the origin/CV and is rotated 45 degrees on the green Y-up axis. On opposing square corners of the PS and on the X axis, point snapping is used to place small spheres to identify the (L.VP and VP.R). On the third corner of the PS, our Front Perspective Camera (FPC) can be snapped into position to set the FPC camera viewing distance (VD) to the world origin (0,0,0). This digital eye is referred to as the Station Point (SP) in technical illustration.

In Fig 2) is a render from Fig 1's **Top Measured Perspective Camera.** At the 3D world space origin the perspective center of vision (CV) is indicated as a small sphere. At this point, and in technical perspective, the leading square edge of the subject to be illustrated is placed directly against our theoretical picture plane and digital red X plane. Only on this theoretical picture plane, from the perspective Center of Vision, and at the digital 3D world origin, a vertical line, called a True Measure Line (TML) can be drawn to measure the scaled height of the subject. This TML is indicated in the 3D scene as the leading edge of the cube.

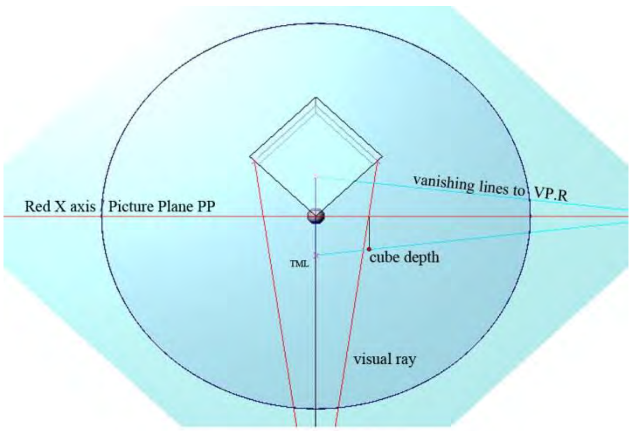

Fig 2. Top Perspective Camera

Also drawn in the 3D Top Orthographic View Camera, but of and for a drawn Front Perspective View is a true measured line of the leading edge of the cube. Centered at the origin and CV the first line of our digital measured perspective illustration is drawn from the center CV up and down. From the True Measure Line (TML) end points, the digital geometry has edit points (EP's) marked with X. From TML's measured and marked points light blue vanishing lines are drawn to the right vanishing point (VP.R). With the cube's leading TML edge and vanishing lines drawn, the remaining challenge is to locate the correct perspective depth.

Following the technical illustration plan projection method, the center of the cubes orthographic corners, on the Horizon Plane are located. Visual Rays (VR) traveling from these rotated cube corners and to the station point (SP), eye point, and 3D front perspective camera position are drawn as red colored lines. To calculate the depth, the visual ray from the cube corners, must turn and project vertically, as it crosses the theoretical picture plane and red X axis. The visual ray's (VR) vertical Projection Line (PL) then travels to intersect with the light blue vanishing line and the their intersection identifies the correct perspective depth of the cube.

This digitally rendered technical illustration shows conventional measured perspective techniques created using 3D digital tools and methods. To verify the accuracy of the method, wireframe renders of the Fig 1) Top Measured Perspective Camera and Fig 2) Front Perspective Camera position were composited and are presented in Fig 3) Front and Top Perspective Composite. To create the test a cube was modeled and rotated 45 degrees in the top view.

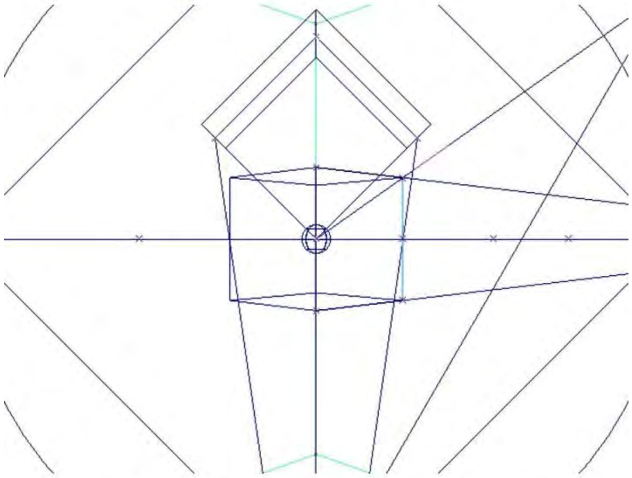

Fig 3: Top and Front Perspective Composition

The 3D digital model of the cube was rendered as a wireframe from the point of view of the Front Perspective Camera. Lines drawn in the Top Orthographic View Panel and rendered from the Top Perspective Camera view are also shown. When transparency composited, the 3D model's perspective render exactly matches the drawn vanishing line angles and perspective cube vertical depth line.

Conclusions

While todays digital tools have antiquated the need to commercially practice Measured Perspective Technical Illustration today's students need a theoretical knowledge and basic applied practical experience in its methods. Furthermore, the programmed technical illustration steps and digital procedures provide students with three part learning opportunities. Students learn the traditional technical, the digital methods to create their counterparts, and develop the knowledge and understanding to apply all in future critical thinking, creative visual problem solving, and digital creation activities. In the future works, additional angled perspectives can be explored as well as the traditional /digital (tra-digital) calculation of light and shadows rays from a light source. As perspective renders are the primary vehicle for calculating digital raytracing of reflections and refractions of light and visual object rays their calculations to the perspective camera within the scene are of interest as they dramatic effect image quality and render time.

References

Pyeatt, A. D. (1960). *Technical Illustration Second Edition*, Brooklyn, NY: Higgins Inc.

Schneerer, W. F. (1967). *Programmed Graphics New York, NY* . McGraw-Hill

Spatial Visualization of Geons through the Modification of the Purdue Visualization of Rotations Test (ROT)

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Abstract

The recognition-by-components (RBC) theory states that humans perceive objects in their environment through the amalgamation of primitive shapes called geons. RBC also suggests that when a novel introduction to an object occurs a new exemplar category is created through the process of primal access that creates a representation of that object in memory. Through this exemplar category humans are able to categorize geons into various objects of recognition. We propose the use of geon pictorials as a replacement to the isometric pictorials found in the Purdue Visualization of Rotations Test (ROT). It is anticipated that the use of geon pictorials will help further our understanding of spatial rotation development in relation to the intrinsic nature of the exemplar category.

Introduction

The Purdue Visualization of Rotations Test (ROT) developed and later modified by George Bodner and Roland Guay consists of a test of 20 questions designed to measure spatial ability through the mental rotation of isometric shapes or pictorials presented to participants through a selection of rotated shapes (Bodner & Guay, 1997). This test is designed to measure the mental rotation abilities of the participants. Other uses for the ROT is to determine if participants have difficulty drawing appropriate information from two-dimensional images on a computer screen and to investigate participants' ability for problem-solving (Bodner & Guay, 1997).

Bodner and Guay (1997) have reported the ROT as being a "valid measure of cognitive abilities" (p. 13). This holds true based on their analysis in which they found high correlation performance between the ROT and the Shepard-Metzler test, ROT scores and students' performance in spatial topics, and problem-solving tasks (Bodner & Guay, 1997). They note, however, their work suggests that a considerable population (within chemistry majors and chemists) have low spatial skills. Bodner and Guay (1997) found that these individuals have developed tricks to solve spatial problems to help in understanding complex cognitive issues found in chemistry. In addition, Bodner and Guay note that spatial ability can be expanded and increased through practice.

Branoff (2000) challenged the validity of the ROT because of its use of isometric pictorials that would be interpreted by some participants as two-dimensional patterns instead of a three-dimensional shape. Branoff (2000) proposed the use of trimetric pictorials to replace the isometric pictorials because of its propensity to create accidental occurrences, thus creating a two-dimensional pattern as seen in Figure 1. Branoff (2000) states that the current ROT cannot truly assess ones' spatial ability due to this limitation with isometric pictorials.

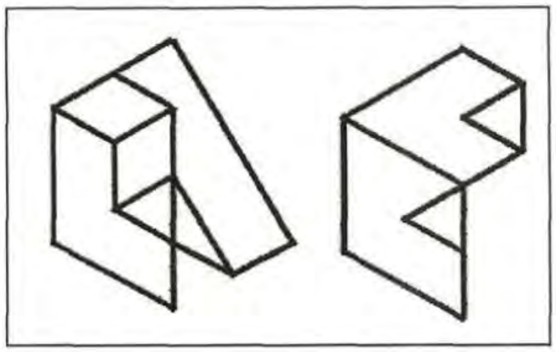


Figure 1. Example of an accidental occurrence of an isometric pictorial (Branoff, 2000).

Branoff (2000) found that the use of trimetric pictorials were no better than isometric pictorials to determine an individual's spatial ability. There was no significant difference between the control (original ROT) and the experimental group (modified ROT). However, Branoff (2000) did find that male participants in the experimental group completed the test in considerably less time (12.59 minutes) than the control group (14.97). Branoff suggests this gap may be due to the difference between isometric and trimetric pictorials. Furthermore, Branoff (2000) states that some participants of the control group experienced confusion on the last several questions of the test, indicating a problem with accidental occurrences that arise from isometric views.

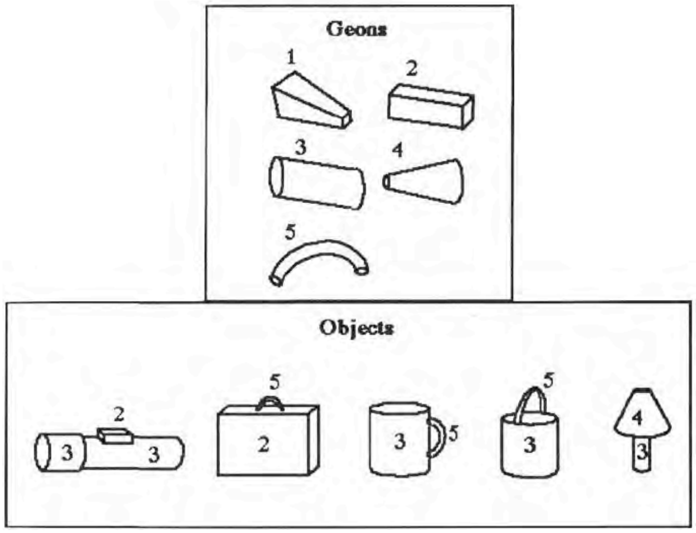
Irving Biederman (1987) developed a theory of 3D shape recognition to explain how humans perceive objects in their environment. Biederman proposed that all objects are created through the amalgamation of primitive shapes called geons. These geons mostly made of blocks, cylinders, wedges, and cones, when combined, form the object to be perceived as seen in Figure 2.

Biederman suggests that objects are rapidly recognized even when viewed through novel orientation, visual noise, partially occluded, and first viewing or what Biederman calls, new exemplar of a category. Object understanding is accomplished through three constraints defined by Beiderman:

1. Access to the mental representation of an object should not be dependent on absolute judgments of quantitative detail, because such judgments are slow and error prone.

2. The information that is the basis of recognition should be relatively invariant with respect to orientation and modest degradation.

3. Partial matches should be computable. A theory of object interpretation should have



some principled means for computing a match for occluded, partial, or new exemplars of a given category. (p. 117)

Figure 2. Examples of Biederman's geons and how they can be used to create other objects. (Biederman, 1987).

Additional geon properties as defined by Biederman (1987) are: (1) view-invariance: each geon can be distinguished from the others from almost any viewpoints except for accidental views at highly restricted angles in which one geon projects an image that could be a different geon, as, for example, when an top-down view of a cone can be a sphere or circle. Objects represented as an arrangement of geons would, likewise, be viewpoint invariant. (2) stability or resistance to visual noise: because the geons are simple they are readily supported by the Gestalt property of smooth continuation, rendering their identification robust to partial occlusion and degradation by visual noise as, for example, when a cylinder might be viewed behind a bush. (3) invariance to illumination direction and surface markings and texture. (4) high distinctiveness: the geons differ qualitatively, with only two or three levels of an attributes, for example straight vs. curved, parallel vs. non parallel, positive vs. negative curvature (Biederman & Gerhardstein,1993).

Biederman (1987) explained that before object recognition can occur there must be what he calls primal access, "the first contact of a perceptual input from and isolated, unanticipated object to a representation in memory" (p.117). In other words, our first contact with an object must be processed into memory prior to continued recognition of that object. This now becomes an exemplar for a new category for recognition to take place. Biederman, Cooper, Hummel, and Fiser (1993) explain further that this process takes place in the absence of any context that might help deduce what the object is. This action increases one's processing time to assimilate that new object. Once assimilated as a new exemplar category humans use this repeated process to learn about their environment (Biederman, et al., 1993). Biederman, et al. add that entry level primal processing becomes the first mode in a child's visual vocabulary that will continue to grow over time.

Other studies by Hoffman (1998), Pizlo (2008) and others suggest similar ideas regarding shape recognition with theoretical backed Gestalt principles, including Biederman's (1987) theory. It should be noted that Gestalt theory of perception fall under Gestalt psychology that was founded back in the late 19th and early 20th century. This area of perception deals with emergence, reification, multistability and invariance. Although some have criticized Gestalt for being simply illustrative and not explaining phenomenon, it has shaped the basis of past and current research into the perception of patterns and objects (Biederman, 1987; Bruce, Green, & Georgeson, 1996; Pizlo, 2008).

Therefore, according to Biderman (1987, 2001), humans understand geons on a primal level and the understanding of exemplar categories are based on geons accessed through memory- this is called a geon structural description (GSD). In addition, GSDs rely heavily on nonaccidental properties (NAPs) of objects which are, for the most part, impervious to rotation in depth cues (Biederman, 2001). Due to the proposed inherent nature of geon perception, humans should be able to perceive these shapes naturally with low cognitive load or what Biederman (1987) referred to as "Gestalt processing" (p. 7) by transforming (processing) the image or object as a structured sum total. Assumptions regarding spatial abilities should be tested on how geons are understood spatially not only perceptually.

Proposed Study

The purpose of the study is to determine if the use of geon pictorials will provide a low cognitive load or to be lest likely complicated by analytical processing- in other words, geons are assumed to be understood with less cognitive processing than its isometric pictorial counterparts found in the ROT. This study does not challenge the validity of the ROT, but will test the geon theory as a means to help understand both spatial and perceptual abilities. Due to the natural process (primal access) that occurs during an individual's life of defining geons, thereby creating exemplar categories to define objects. This study hopes to find a connection between active cognition and spatial ability (Biederman, 1987).

Methodology

Research Design

This study will model the original studies by Bodner and Guay (1997) and Branoff (2000) but with the modification of the isometric (and trimetric) pictorials being changed to a set of 20 geons originally developed by Biederman (1987). This study will include a computer-based version of the Mental Rotations Test (MRT), which is based on the Shepard-Metzler Rotations test (Bodner & Guay, 1997, Branoff, 2000). This will provide a secondary measurment for both the control and experimental groups (Bodner & Guay, 1997, Branoff, 2000).

Participants

Students will be recruited from courses at Purdue University within the College of Technology. These students will be randomly assigned to either the control or the experimental group. The participants will be asked to complete the tests in a controlled lab environment using a computer-based version of each test.

Instrumentation

This study will utilize computer-based geon-Purdue Visualization of Rotations Test (modified ROT), original Purdue Visualization of Rotations Test (original ROT), and the Mental Rotations Test (MRT) all consisting of 20 questions. According to Bodner and Guay's (1997) study, pictorials were rotated 90˚ on one access with another rotation of 180˚ on the same axis. Some later pictorials require rotations of 90˚ on one axis and 180˚ on a different axis. The MRT requires a selection of two correct and incorrect choices (Branoff, 2000).

Development

The creation of a computer-based version of the ROT using geons is still in an early preliminary design stage of development. It is anticipated the researchers will develop approximately 21 geon pictorials to be used for testing (an example of Biederman's (1987) original geons are found in Figure 3). The additional geon pictorial will be used for the rotation example and the remaining 20 will be used for the selection of rotation on each question. The time for the test will remain at 10 minutes as defined in the original ROT study.

Conclusion

It is anticipated that the replacement of the isometric pictorials with geons may provide some additional insight on spatial ability dealing with mental rotation of objects. The use of geons with its theorized creation through primal access allows us to use an inherent level of perceptual understanding or a bottom-up approach, something that may be lost in the current version of the ROT. Although, both Bodner and Guay's (1997) and Branoff's (2000) studies found results indicating that the ROT and the modified ROT are good measures of 3D spatial visualization. This geon-based test may also provide further insight to our understanding of geon theory and help broaden our understanding of spatial rotation development in relation to the intrinsic nature of how humans perceive objects spatially.

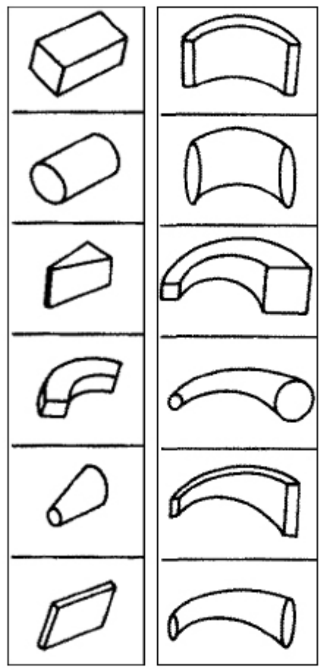


Figure 3. Examples of Biderman's geons (Biederman, 1987).

References

Biederman, I. (2001). Recognizing depth-rotated objects: A review of recent research and theory, *Spatial Vision*, *13*(2-3), 241-253. VSP, an imprint of Brill.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding, *Psychological Review, 94*(2), 115-147.

Biederman, I., Cooper, E. E., Hummel, J. E., & Fiser, J. (1993). Geon theory as an account of shape recognition in mind, brain, and machine. In J. Illingworth (Ed.) *Proceedings of the Fourth British Machine Vision Conference*, 1, 175-186. Surrey, U.K.: BMVA Press.

Biederman, I., & Gerhardstein, P. C. (1993). Recognizing depth-rotated objects: Evidence and conditions for three-dimensional viewpoint invariance, *Journal of Experimental Psychology Human Perception and Performance*, *19*(6), 1162-1182.

Bodner, G. M., & Guay, R. B. (1997). The Purdue Visualization of Rotations Test. The Chemical Educator, 2(4), 1-17. Purdue Research Foundation. Retrieved from http://www.springerlink.com/index/10.1007/s00897970138a.

Branoff, T. (2000). Spatial visualization measurement: A modification of the purdue spatial visualization test—visualization of rotations, *Engineering Design Graphics Journal, 64*(2), 14-22.

Bruce, V., Green, P. R., & Georgeson, M. A. (1996). Visual perception : Physiology, psychology, and ecology, *British Journal of Psychology* (p. xiii, 433). Psychology Press. Retrieved from http://elib.tu-darmstadt.de/tocs/110626923.pdf.

Hoffman, D. (1998). *Visual intelligence: How we create what we see*. New York, NY: W. W. Norton & Company.

Pizlo, Z. (2008). 3D shape: Its unique place in visual perception. MIT Press.

The Effectiveness of Real & Augmented Models to Advance the Spatial Abilities of Visual/Haptic Engineering Students

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Abstract

Advances in augmented reality technology have drastically lowered the cost associated with its implementation. This has enabled the use of augmented reality in higher education courses. This paper and presentation reports the results of a research study conducted during the Fall Semester of 2011 at Purdue University. This study compared the use augmented and real models as visualization aids for first year engineering students enrolled in an entry level engineering graphics course. The paper will present the significance of this research study, the research methodology, statistical findings. It will infer conclusions made by the authors and will suggest future studies and applications for the integration of both augmented and real models as visualization aids to advance the visualization abilities of engineering students.

Introduction

This study focused on advancing spatial abilities for entry-level engineering students, related to engineering graphics. The problem of the study was to determine if the use of augmented reality blocks or real blocks (different instructional methods) would advance spatial ability in students who possess different learning styles of visual or haptic.

The literature indicated that not all students possess the same learning styles or spatial abilities; this study focused on the learning style of visual/haptic (Lowenfeld, 1945; Miller, 1992; Study, 2001). Employing an instructional method of augmented reality or real blocks, the study asked which instructional method helped advance the spatial abilities of subjects who possess either visual or haptic learning style. The research was done in the context of an engineering graphics course that relies heavily on visualization abilities.

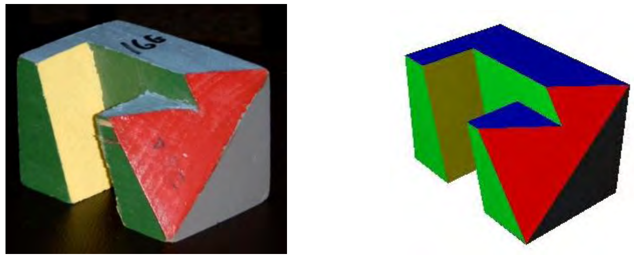

Figure 1. An Example of a Real Block (left) and an Augmented Reality Block (right)

This study implemented the use of cutting edge, innovative technologies, such as augmented reality, to aid students in spatial ability advancement. The study was being utilized to test these new innovative approaches to understand if the technology really is helpful in aiding students in advancing spatial skills. This study divided the students into two different learning styles to understand how different learning styles can have an impact on spatial skill advancement depending on different instructional methods.

Methodology

This section describes the methodology used for the study, including the instrumentation. The study was performed at Purdue University at the West Lafayette, Indiana campus, in the fall semester of 2011. The course utilized to recruit participants from was CGT 163, Introduction to Engineering Graphics. This course covers topics that require visualization abilities such as, multi-view orthographic sketching, pictorial isometric sketching, and 3-D modeling in computer-aided design (CAD) programs. The course is required for Mechanical Engineering (ME) and Aeronautical and Astrological Engineering (AAE) students and majority of them fulfill this requirement in their first two years of their curriculum at Purdue University.

The methodology of the study employed a sample of participants that was split into two groups determined by the Purdue Spatial Visualization Test (PSVT) and the Haptic/Visual Discrimination Test (HVDT). These two tests divided the participants into students that learned with visual tendencies and students that learned with haptic tendencies. Participants in each group were randomly selected to use either the augmented reality or the real blocks instructional method.

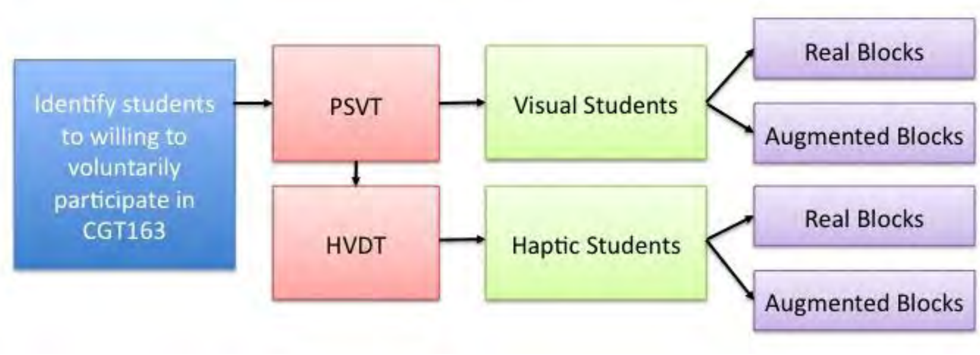

Figure 2. Flowchart of Methodology

First the PSVT was administered in the CGT 163 lecture during the first week of classes, to all the students who were present in lecture on that day. The PSVT is a visual test used to measure spatial ability. It consists of three parts: developments, rotations, and views (Guay, 1976). Developments are the folding of shapes into three-dimensional objects (Guay, 1976). Rotations are designed to “help visualize the rotation of a three-dimensional object” (Guay, 1976, p.6). Views are what the three-dimensional object looks like from different views (Guay, 1976). The participants took the whole test, as all parts of the test are related to engineering graphics. 370 students took the PSVT on this day. Students who scored a 95% or better on the PSVT were considered visual students. These students were asked to sign up for the block test as participants in the visual group.

Figure 3. HVDT Objects (left) and HVDT Set-Up (right)

Students who scored lower that 95% were asked to sign up to take the HVDT during the second week of classes. 71 students took the HVDT during this week. The HVDT is an individual test that determines if a participant’s learning style is haptic; that is, learning with tactile and touch as opposed to visually. The test consists of a participant reaching through a screened frame (where they cannot see what is through the screen) and holding an object. Next, the participant is asked to identify the object in their hand, without looking at it, from an identification chart. There are four criteria: shape, size, texture, and configuration. The student receives a score depending on how well they identify these characteristics of the object (Study, 2001). Students who scored a normal score of above 100 (average) were considered to possess haptic tendencies and they were asked to sign up for the haptic group for the block testing.

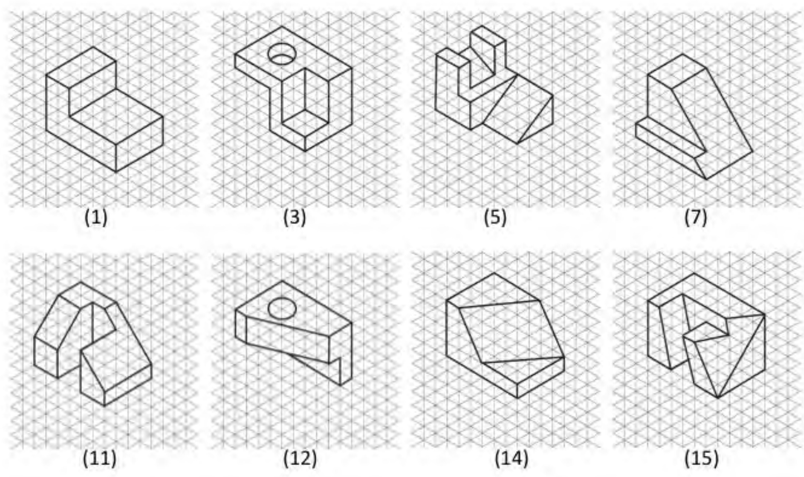

Figure 4. All Eight Blocks Illustrated in Isometric Views

The students were then split into the two learning style groups of visual and haptic students determined by the PSVT and HVDT respectively. Next, the instructional treatment was started and continued for the next three weeks. 67 students were tested, 29 haptic and 38 visual. During the block testing, each student received eight different cut-blocks ranging in difficulty from simple to complex. The subject constructed these blocks as multi-view sketches. Every student received the same eight cut-blocks, in the same order. Each student received eight worksheets. On each worksheet the isometric or pictorial view of the cut-block was illustrated along with an orthographic grid to sketch the multi-view of the cut-block. The students were randomly assigned into one of two instructional methods; real or augmented reality blocks. The worksheets were then gathered and scored for accuracy. Each cut-block had a corresponding score sheet. Students received a set amount of points for sketching the different features of each cut-block correctly in all three views.

The main objective of this study was to determine the effect of real versus augmented models on spatial ability based on haptic or visual learning style of entry-level engineering graphic students. A nested univariate repeated measures ANOVA test was used to determine if there was an interaction between learning style and instructional method.

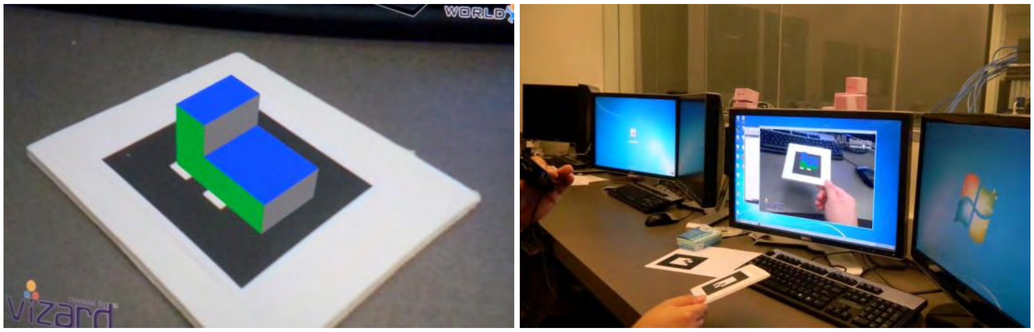

Figure 5. Example of an Augmented Block Viewed from the 3-D Glasses (left) and the Augmented Reality Set-Up (right)

Findings

The findings of this study were based on the research hypothesis, what is the effect of real versus augmented models for the advancement of spatial ability based on haptic or visual learning style of entry-level engineering graphics students? The hypothesis was tested at 0.05 level of probability using a nested univariate repeated measures ANOVA test. The hypothesis that was investigated in this study focused on how entry-level engineering students, divided into visual and haptic learners, advanced their visualization abilities in engineering graphics using either augmented reality or real blocks. The hypothesis focused on the interaction between learning style (visual or haptic) and instructional method (augmented reality or real blocks). Which method aided which type of learning style best? The statistical findings gave a P-value of 0.137, which is higher than the alpha level of 0.05, indicating that the interaction between learning style and instructional method was not significant. Meaning either instructional method would aid either learning style equivalently.

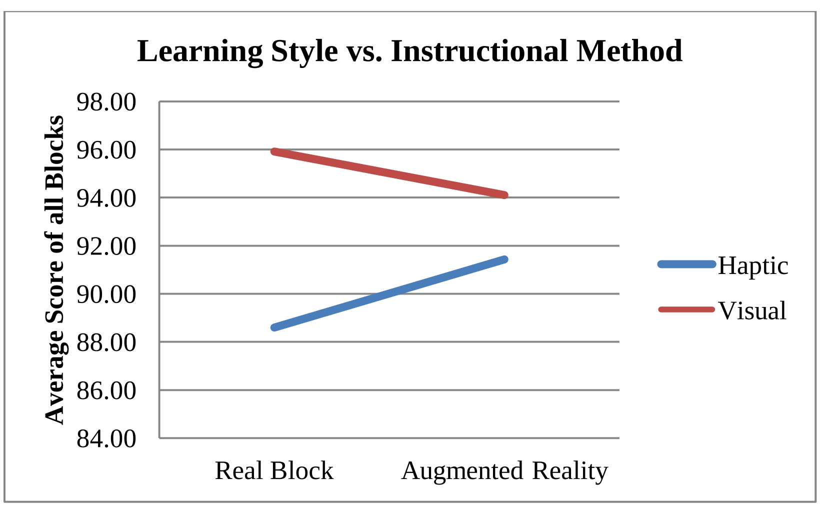

Figure 6. Learning Style vs. Instructional Method

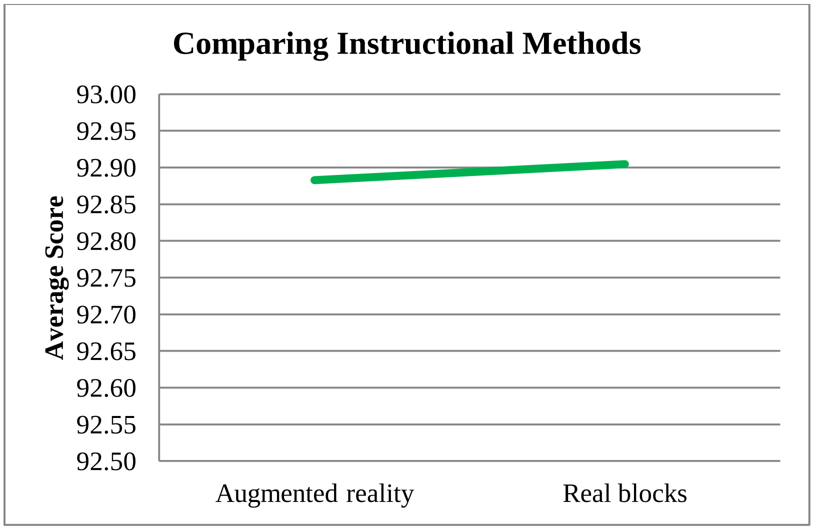

Figure 7. Comparing Instructional Methods

However, there were other factors included in the statistical analysis that the hypotheses did not directly address. These factors include learning style, instructional method, block, learning style by block, instructional method by block, learning style by instructional method by block, and subject-to-subject variance. It was important to include these statistical findings of these other factors because the findings support the hypothesis results and enlighten some areas for future study. From the ANOVA model it was found that learning style, block, learning style by block, learning style by instructional method by block, and subject-to-subject variance were statistically significant.

Dependent Variable: Score on Blocks

Source/contrast	**df**	**Mean Squares**	**F-value**	**P-value**
Learning Style	1	3279.147	10.494	0.002*
Instructional Method	1	31.164	0.1	0.753
Learning Style x Instructional Method	**1**	**709.436**	**2.27**	**0.137**
Subject-to Subject Variance	69	312.479	6.114	0.000*
Block	7	1816.142	35.533	0.000*
Learning Style x Block	7	197.691	3.868	0.000*
Instructional Method x Block	7	34.981	0.684	0.685
Learning Style x Instructional Method x Block	7	142.185	2.782	0.008*

***p<.05**

Table 1. Nested Univariate Repeated Measures ANOVA Results

Learning style significance can be supported from the literature of prior research in this area. Visual students generally performed better at spatial tasks including visualization than haptic students (Lowenfeld, 1945; Miller, 1992; Study, 2001). This is shown from the literature and was supported from the results of this study. In the study, visual students outperformed haptic students on every block.

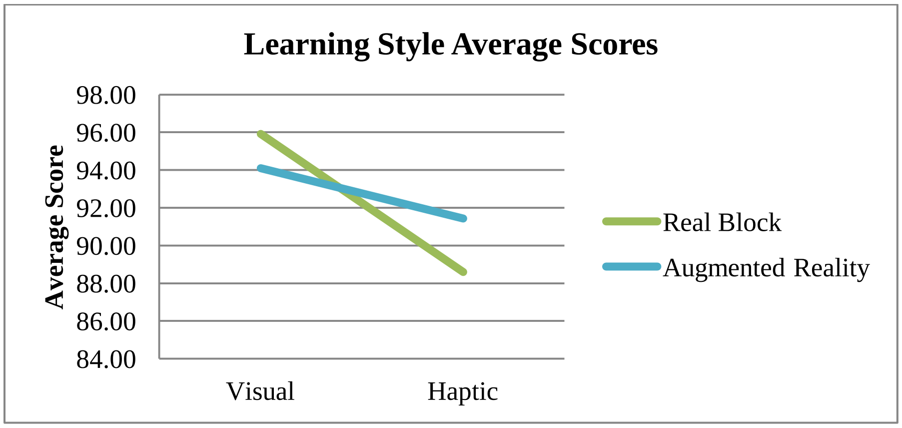

Figure 8. Learning Styles Average Scores

The complexity level of the blocks was also statistically significant. It was determined that more complex blocks, determined by inclined and oblique features or type of planes, were harder to visualize than a block that did not have these abstract features. A less complex a block was defined as possessing features or planes that were horizontal of vertical.

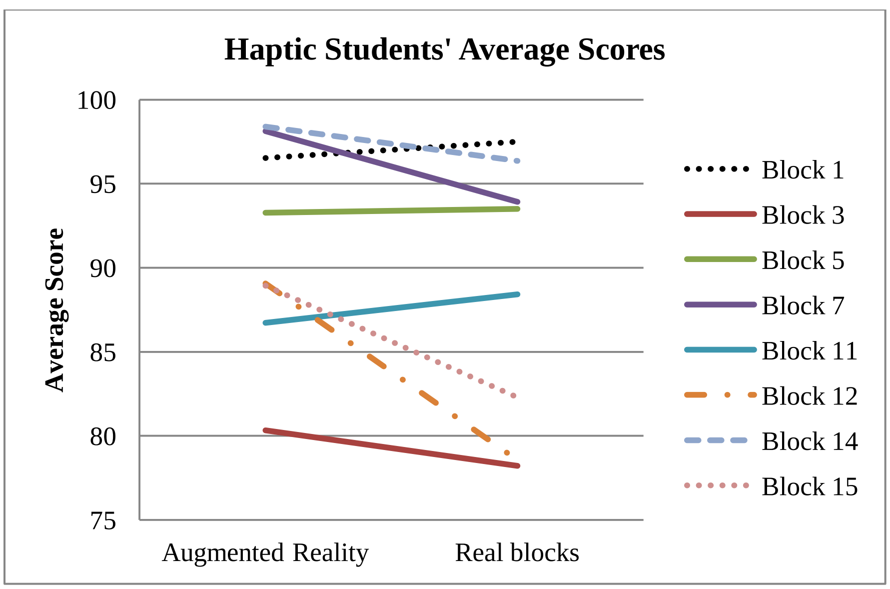

Figure 9. Haptic Students' Average Scores

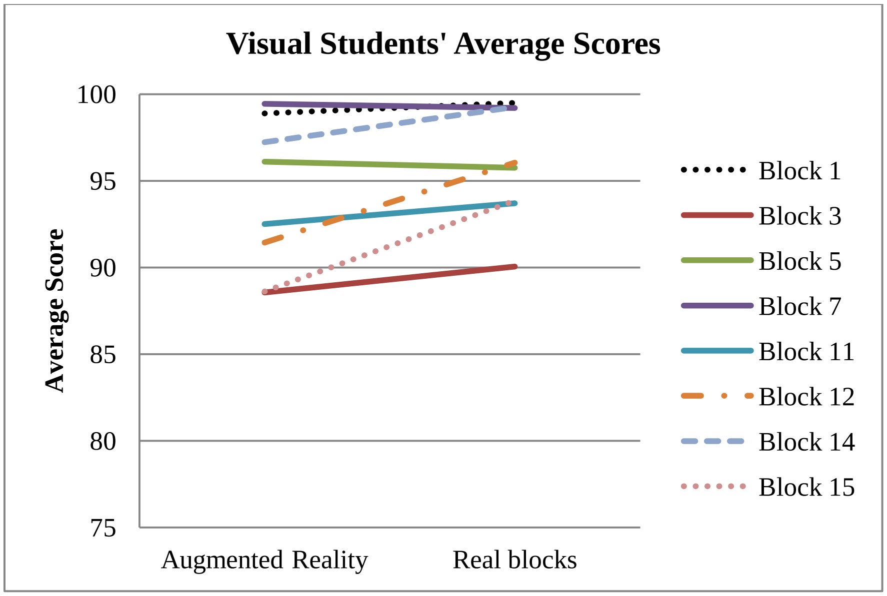

Figure 10. Visual Students' Average Scores

The ANOVA model classified the interaction between learning style and complexity level of block as statistically significant. Visual students tend to score higher than haptic students while comparing the overall mean scores of all the blocks. This is true even when the instructional method was not taken into account.

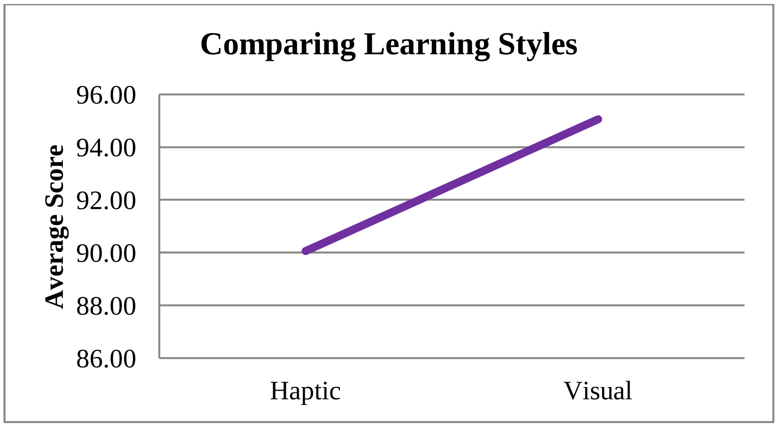

Figure 11. Comparing Learning Styles

The interaction between learning style, instructional method, and complexity of the blocks was also found to be statistically significant with the ANOVA model. Again, it can be inferred that visual students generally outscored haptic students independent of the block complexity and the instructional method. However, this interaction being statistically significant infers that the learning style, block complexity, and instructional method develop an influence on how well a student scored.

Subject-to-subject variance is the last factor that was found statistically significant in the ANOVA model. Basically, each student was not identical with the next student, because each student possessed different internal factors that have developed their spatial abilities and visualization skills over their lives. Some students might have played with more spatial sensing toys as children such as Legos, some students might have taken a drafting class in high school, some students might just be inheritably better at these skills than others. Subject-to-subject variance accounts for these potential differences in the statistical model. This factor was significant in the study because any one of these differences and the combination of them made each student unique in their spatial abilities of the sample of students chosen to participate.

Discussion of the Findings

The data does not support the research hypothesis that the two different instructional methods (real or augmented blocks) should be employed depending on the learning style (visual or haptic). The data supports that either instructional method that was used, would help students of either learning style advance their spatial abilities.

Learning Style

One might have thought that real blocks would aid haptic students more so than the augmented reality blocks. The research contends that haptic students learn through tactile interaction with an object. Since the real blocks could be held and felt as opposed to the augmented reality blocks that cannot; this fact lead the researcher to believe that the real blocks might be more beneficial than augmented reality blocks for haptic students. This however, was not the case. Haptic students did equally as well with augmented reality and real blocks, in this study. Future research should be repeated to confirm these results.

Students who are identified as visual are likely to be better at visualization skills than haptic students according to the results of prior research studies (Lowenfeld, 1945; Miller, 1992; Study, 2001). Both the augmented reality and real blocks aided visual students in an equivalent way. This result might be what is expected to happen since visual students are better with spatial skills in general. It might be beneficial to test visual students again, with more challenging blocks.

The statistical result of learning style being significant in this study follows what the literature has theorized about visual or haptic students possessing spatial abilities (Lowenfeld, 1945; Miller, 1992; Study, 2001). The results indicate that visual students seem to have a higher capacity to understand spatial problems and tasks than haptic students, no matter what the aid is. Students who used real blocks or augmented blocks that were designated visual students did better overall than haptic students. This signifies that learning style does make a difference in student's spatial abilities, which also follows the statistical evidence from this study.

Visual learners may possess the required spatial abilities required to visualize, making the augmented reality or real block aid irrelevant. The visual learner may not need an aid to help visualize the cut-block. The literature suggests that no matter the instructional method, haptic learners may still struggle with visualization because their learning style does not complement visual tasks such as block exercises (Lowenfeld, 1945; Miller, 1992; Study, 2001).

Subject-to-Subject Variation

Subject-to-subject variance refers to the differences each student might have compared to another student, related to engineering graphics. For example, some students might have taken an engineering graphics course in high school, or might be genetically better at spatial ability and visualization than the next student. Subject-to-subject variance takes these possible differences into account in the statistical model (Montgomery, 2009).

These differences in the students could have impacted the overall study. Some students may have taken a previous course in engineering graphics or are inheritably better at spatial cognition. It is impossible to use identical participants because of background experiences and other factors make them different from each other. Accounting for these individual subject differences using subject-to-subject variance in the statistical model increased the validly of the study.

Augmented Reality Technology versus Real Blocks

The study suggests, from the conclusion of the hypothesis that the two different instructional methods did not seem to help or hurt either the visual or haptic learners. The statistical conclusion of the hypothesis also suggests that either the augmented reality blocks or the real blocks could have equal potential in helping students learn visualization skills. The results of the study suggests that augmented reality blocks have a greater potential of getting students interested in learning visualization skill from the expressions of a majority of the students who used the augmented reality blocks.

The augmented reality blocks used some of the newest technologies to help students develop spatial abilities. However, this study implies that real wooden blocks helped students of both visual and haptic learning styles equally as the augmented reality blocks. Additional research in this area is suggested to understand the cost effectiveness versus learning benefit of each instructional method. It is also noted, that the augmented reality Vizard system that was used in this study, was not practical for a large class. Research should also be investigated in using more practical devices such as smart phones and tablets to receive the same results.

The technology of augmented reality might sound very appealing to most educators and students. Using this innovative technology to convey learning and skills needed for the classroom and beyond is one way to get students interested and eager to learn. However, if a less motivating, less expensive method is thought to be equally as successful in advancing the visualization abilities of students then which method does an educator choose? This decision should be made by considering the costs of augmented reality versus the cost of producing real models and how successful each method is in advancing students' spatial abilities. There needs to be more research done in this area, and as the costs decrease and availability of new augmented reality systems become more available than the use of this technology could be considered for implementation. There are many new developments that can be made with tablets and smart phones that may be far less expensive than the Vizard augmented reality system that was used in this study and might benefit students in developing spatial skills. Engineering education could potentially benefit greatly by exploring the uses of new and old technology in developing spatial skills in future engineers. Further research should be done to understand the uses of technology such as smart phones and tablets to develop visualization skills in engineering education.

Conclusions

The conclusions of this study were based on its research hypothesis. The following conclusions were drawn based upon the statistical analysis and findings. It can be concluded that:

- The learning style of either visual or haptic impacted on how well students advanced spatial skills based on the orthographic cut block evaluation. Visual students developed and performed better on spatial tests than haptic students.
- The instructional method of augmented reality blocks or real blocks had no effect on students of different learning styles of visual/haptic in aiding in their development of spatial skills.

Recommendations

The review of literature, experiences of the researcher during the study, and the statistical results of it serve as a basis for several recommendations. These recommendations are directed to educators and future researchers in spatial ability advancement, learning styles, and instructional methods.

- Repeat the study using more challenging blocks. In this study some blocks were very challenging while some were very simple. If this study was to be repeated the very simple blocks should be replaced with more challenging ones. Repeating the study with more challenging blocks may give a more accurate analysis of this thesis.
- Even though augmented reality blocks were proven to help students equally as real blocks, several students were excited about the 3-D glasses and using an augmented reality system. This eagerness to learn might make augmented reality blocks worth the investment in this technology in the future. However, it is believed, with more research,

applications for smart phones and tablets could be developed to receive a similar effect as the Vizard system. The Vizard system that was used in this study would not be cost effective for a large multi-lab section course. These different technologies might be both cost effective in implementation and motivational for the students to want to use.

- Comparing the cost effectiveness of mass producing the real blocks and developing new applications for smart phones and tablets. This is important to understand, from a standpoint of being cost effective. Instructional methods for advancing spatial skills in students need to be both effective and affordable.
- Exploring in depth the fundamental differences between visual and haptic learners to understand how they learn. This could help academia better understand how to teach these different learning styles of students. This study adds to the many previous studies that acknowledge visual learners as students who possess well-developed spatial abilities while haptic students seem to struggle with spatial abilities. Exploring the fundamental differences in these learning styles could potentially help develop creative methods of teaching to help students of both learning styles.

These recommendations could potentially find a new creative way of learning in the classroom in the realm of engineering graphics and spatial abilities coupled with the implementation of new technologies.

References

Anderson, G., Fruchter, B. Manuel, H. T., & Worchel, P. (1954). *Survey of research on spatial factors*. Lackland, TX: Air Force Personal Training Research Center.

ANSI: Historical Overview. (n.d.). . Retrieved April 10, 2011, from http://www.ansi.org/about_ansi/introduction/history.aspx?menuid=1

Azuma, R. T. (1997). A survey of augmented reality. *Teleoperators and Virtual Environments, 6,* 355-385.

Berry, M. & Genskow, J. (1986). Haptic visual discrimination and cognitive functioning. *Vocational Evaluation and Work Adjustment Bulletin, Spring,* 15-17.

Beroline, G. R. & Weibe, E. N. (2005). *Fundamentals of Graphics Communications Fifth Edition*. New York, New York: McGraw-Hill.

Branoff, T. J. (2000). Spatial visualization measurement: a modification of the Purdue spatial visualization test- visualization rotations. *Engineering Design Graphics Journal. volume 64, number 2*, 14-22.

Carroll, J. B. (1993*). Human cognitive abilities*. New York: Cambridge University Press (pp.30-72/Chapter 2).Connolly, P. E. (2009). Spatial ability improvement and curriculum content. *Engineering Design Graphics Journal. volume 73 number 1,* 1-5.

Devore, J. L. (2008). Multifactor analysis of variance. In C. Crockett (Ed.), Probability and Statistics for Engineers and the Sciences 7th Edition (pp.397-445). Belmont, CA: Thompson Brooks/Cole.

Eals, M., & Silverman, I. (1994). The hunter-gatherer theory of spatial sex differences: proximate factors mediating the female advantage in recall of object arrays. *Ethnology and Sociobiology 15*, 95-105.

Earl, J. H. (1987). *Engineering design graphics*. Reading, MA: Addison-Wesley.

Eliot, J., & Smith, I. M. (1983). *An international directory of spatial tests*. Windsor, Berkshire: NFER-NELSON.

El Koussy, A. A. H. (1935). The visual perception of space. *The British Journal Of Psychology*, Monograph supplements, 1-80.

Envision Center at Purdue University website (n.d.). Retrieved August 1, 2011, from www.envision.purdue.edu/about.html.

Fisher-Thompson, D. (1990). Adult sex typing of children’s toys. *Sex Roles*, *23*(5), 291–303.

Griffith, A. L. (2010). Persistence of women and minorities in STEM field majors: is it the school that matters?. *Economics of Educational Review, 29,* 911-922.

Guay, R. (1976). *Purdue Spatial Visualization Test.*

Guay, R. B. (1980, April). *Spatial ability measurement: A critique and an alternative.* Paper presented at the Annual Meeting of the American Educational Research Association, Boston, MA.

Harris, L. J. (1978). Sex differences in spatial ability: possible environmental, genetic, and neurological factors. In M. Kinsbourne (Ed.), *Asymmetrical Function of the Brain*. Cambridge: Cambridge University Press.

Hartman, N. W., Connolly, P. E., Gilger, J. W., Bertoline, G. R., & Heisler, J. (2006). Virtual reality-based spatial skills assessment and its role in computer graphics education. *ACM SIGGRAPH 2006 Educators program* (p. 46–54).

Kelley, T. L. (1928). *Crossroads in the mind of man*. Stanford, CA: Stanford University Press (pp.1-23/chapter 1)

Kaufmann, H., & Meyer, B. (2008). Simulating educational physical experiments in augmented reality. *ACM SIGGRAPH ASIA 2008 educators program* (p. 1–8).

Lohman, D. F. (1988). Spatial abilities as traits, processes, and knowledge. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 4, pp. 181-428). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lohman, D. F., & Kyllonen, P. C. (1983). Individual differences on solution strategy on spatial tasks. In Dillon & Schmede (Eds.), *Individual differences in cognition* (Vol 1, pp. 105-132). New York:Academic Press

Lowenfeld, V. (1945). Tests for visual and haptical aptitudes. *American Journal of Psycholog*y (58, pp. 100-112).

Luzadder, W. J., & Duff, J. M. (1989). *Introduction to engineering drawing*. Prentice-Hall: Englewood Cliffs, NJ.

Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CA: Stanford University Press (pp. 63-133/chapter 3).

McCarron, L. T., & Dial, J. G. (1988). *Sensory Integration: The Haptic Visual Processes.* McCarron-Dial Systems Inc.

McGee, M. G. (1979). Human spatial abilities: *Sources of sex differences*. New York: Praeger Publishers.

Miller, C. L. (1992). *The effectiveness of real- and computer-generated models to avance the spatial abilities of visual/haptic engineering students* (Doctoral dissertation, The Ohio State University). Retrieved from Proquest.com

Mohler, J. (2011). [Notes from CGT 600 at Purdue University]. Unpublished raw data.

Mohler J. L., & Miller, C. L. (2008). Improving spatial ability with mentored sketching. *Engineering Design Graphics Journal, volume. 72 number 1*, 19-27.

Montgomery, D. C. (2009). Nested and split-plot designs. In J. Welter & J. Foxman (Eds.), *Design and analysis of experiments* (pp. 542-556). Hoboken, NJ: John Wiley & Sons, Inc.

Newcombe, N. S., & Learmonth, A. E. (2005). Development of spatial competence. In P. Shah & A. Miyake (Eds.), The Cambridge Handbook of Visuospatial Thinking. New York: Cambridge University Press.

NIST/SEMATECH. (June 6, 2003). Two-Way Nested ANOVA. In *NIST/SEMATECH e-Handbook of Statistical Methods* (3.2.3.3.). Retrieved from http://www.itl.nist.gov/div898/handbook/ppc/section2/ppc233.htm.

Nordvik, H., & Amponsah, B. (1988). Gender differences in spatial abilites and spatial activity among university students in an egalitarian educational system. *Sex Roles*, 38(11/12), 1009-1023.

Olson, D. R., & Bialystok, E. (1983). *Spatial cognition: the structure and development of mental representation of spatial relations*. London: Lawerence Erlbaum Associates.

Sekaran, U., & Bougie, R. (Eds.). (2010). *Research methods for business 5th edition.* West Sussex, United Kingdom: John Wiley & Sons Ltd.

Sorby, S. (2009). Educational Research in Developing 3-D Spatial Skills for Engineering Students. *International Journal of Science Education*, *31*(3), 459-480. doi:10.1080/09500690802595839

Study, N E. (2003). Haptic abilities of freshman engineers as measured by the haptic visual discrimination test. *Engineering Design Graphics Journal*, vol. 67 number 3, 29-34.

Study, N. E. (2001). The effectiveness of using the successive perception test I to measure visual-haptic ability in engineering students (Doctoral Dissertation, Purdue University). Retrieved from Proquest.com

Thurstone, L. L. (1950). Some primary abilities in visual thinking. *Proceedings of the American Philosophical Society*, 94(6), 517-521.

Veurink, N. L., Hamlin, A. J., & Kampe, J. C. M. (2009). Enhancing Visualization Skills-Improving Options aNd Success (EnViSIONS) of Engineering and Technology Students. *Engineering Design Graphics Journal, volume. 73 number 1-17.*

The Intermediate Role of the Visuo-Spatial Sketchpad in Developing Sketching Expertise

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Abstract

'Short term (working) memory' is a complex subsystem of the cognitive architecture. It involves a range of interacting subcomponents which provide an interface between memory, attention and perception (Baddeley, 1998; Stillings, 1995). One such subcomponent of working memory is the 'visuo-spatial sketchpad'. This short term store of visual information plays a critical, intermediate role in developing the necessary cognitive skills required to utilise freehand sketching as an automatic, sense-making conceptual support tool.

This paper presents the findings of a study carried out with a cohort of 137 undergraduate students of initial technology teacher education. Subsequent to developing slow, controlled and reflective observational sketching skills, the students completed several memory based exercises. The purpose of these was to develop the ability to acquire, retrieve and communicate graphical information.

Observations recorded during the memory exercises revealed that the students utilised a number of different strategies in forming visual mental images. Generated sketches were generally consistent with the target configurations; however it was evident that some students had difficulty with correctly orientating some of geometries especially when the complexity increased. General feedback from the students highlighted the difficulties encountered during the activity and it was largely considered as both cognitively challenging and beneficial to the development of graphical skills.

The paper concludes by discussing the importance of understanding the role of human memory systems in developing the ability to engage in complex cognitive modelling of visual mental imagery through the medium of freehand sketching.

Introduction

The effective use of freehand sketching as a problem solving, conceptual support tool is dependent on the ability to build, retrieve, manipulate and synthesise graphical libraries of visual mental imagery (Lane, 2011). Visual mental imagery is critical to visual functions in terms of:

- Comparing distances among objects not physically present.
- Comparing angles between and orientation of objects when viewed from different vantage points.

- Verifying that a new object lies along a particular direction in relation to previously observed objects.
- Developing the skill of mentally anticipating the consequences of visual movement (Finke, 1986).

This paper reports on the findings of a research study conducted with a group of undergraduate students within initial technology teacher education. A number of memory based exercises were completed as an element of a third year, *'Design and Communication Graphics'* module of study. The pertinent research literature associated with the study is presented in the next section where the main focus is on how humans store and remember information through different memory systems.

Memory

The completion of complex cognitive tasks is based on the retrieval of large amounts of information from memory (Ericsson, 1995) or the ability of living organisms to acquire, retain and use information (Tulving, 1987). One of the most interesting aspects of human cognition is the ability to remember facts and previous events when needed. Memory situations can be broken down into three discrete features: "*acquisition"* when the target knowledge is acquired (e.g. learning that a hexagon is a polygon with six sides and six vertices), "*retrieval"* when the target knowledge is accessed for utilisation in some cognitive process and "*retention interval"* is the time between the acquisition and retrieval stages when knowledge is stored (Stillings, 1995).

Storage of acquired target information is carried out by construction of a "*memory trace"* (Tulving, 1991) in the cerebellum of the brain (Krupa, 1993; Stillings, 1995) through particular memory systems. Utilisation of different memory systems depends on the level of activation on acquisition and the retrieval period. Formation of new knowledge depends on the construction of controlled processes or encoding strategies that result in information being retrieved from short-term memory or transferred to long-term memory storage (Stillings, 1995).

Memory Systems

The classical theory of the cognitive architecture (Stillings, 1995) includes three types of memory: working memory (short-term), declarative and procedural (both long term). Long term memory can be divided into three parts: Declarative Memory, Procedural Memory and a Perceptual Representation System (PRS) (Nilsson, 2003; vanGorp, 1999). Within graphics education, memory systems are of particular interest in understanding the complex cognitive processes associated with how graphical problems are solved through freehand sketching. The research method presented in this paper was grounded in the literature associated with short term memory.

Short term memory and sketching

Short term (working) memory is a complex system that involves a range of interacting subcomponents that provide an interface between memory, attention and perception (Baddeley, 1998; Stillings, 1995). Integral to the model of working memory is a central executive and two subsystems (Figure 1), specifically, the *"phonological loop"* and the *"visuo-spatial sketchpad"* (Baddeley, 1998; Bruyer, 1998) which function independently of each other. The phonological loop consists of a *"phonological store"* and an *"articulatory recapitulatory system"* (e.g. these are utilised when a person learns new sounds or words). The visuo-spatial sketchpad stores visual, non-verbal information in short term memory (e.g. the shape of an artefact which a person must memorise and then communicate shortly afterwards) (Baddeley, 1998; Bruyer, 1998).

Figure 1 - Model of working memory proposed by Baddeley (1998)

The *'visuo-spatial sketchpad'* was of particular interest to this study in terms of understanding how students' prerequisite graphical libraries can be stimulated and how these can be further developed through novel sketching tasks. In order to address deficiencies in the research literature associated with freehand sketching, Lane (2011) devised and empirically validated a model of activities (Figure 2) which facilitated the development of sketching expertise.

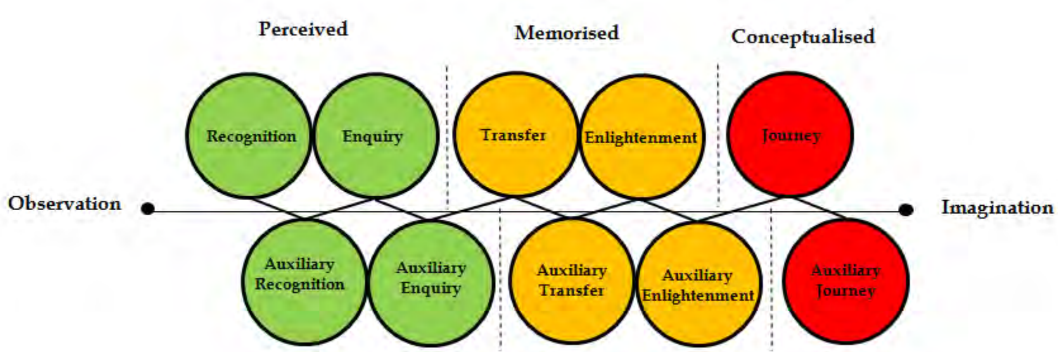

Figure 2 - Model of drawing and sketching activities

The model progresses from left to right where the perception based '*drawing'* activities on the left are controlled and reflective in nature with a high degree of visual scaffolding. In contrast, the conceptual '*sketching'* activities on the right are automatic and reflexive in nature and the visual scaffolds are removed. The strength of the model lies in its potential to promote students' progression across the three stages of development through perceived, memorized and conceptualized activities. The perception based activities build students' *"graphical libraries"* (Storer, 2008) as they are constantly able to refresh vivid perceptual snapshots while composing their sketches (Fish, 1990). The memory focused activities in the centre of the model develop student's ability to access their *"graphical libraries"* of *"visual mental imagery"* (Borst, 2008) and to communicate these through sketching. The final conceptually focused phase of the model promotes students ability to manipulate and synthesize their *"graphical libraries"* through tasks which are imaginative and reflexive in nature.

Previous research (Lane et. al., 2009, 2010) highlights the benefits and implications of the perception focused activities within the model. Through these activities it was found that students could draw from observation with high levels of accuracy in a slow, controlled and reflective manner. The challenge within the study presented in this paper was to provide an intermediate for progressing away from observational based drawing, towards sketching entirely from imagination. In order to achieve this it was necessary to focus on memory type exercises which promoted the retrieval and communication of visual mental images with limited use of visual stimuli.

Research Method

The focal point of this paper centres on the *'Enlightenment'* activity. This is a key stage within the memory focused activities of the model illustrated in Figure 2. The activity was conducted as part of a graphics module in which the development of sketching expertise was a core learning outcome.

Approach

The students were presented with five separate geometric configurations which they then had to communicate from memory. The configurations shown in Figure 3 were used as they were; closely related to the student's course of study and therefore they supported the development of visual imagery. The range in complexity of the configurations was considered appropriate to promote increased levels of cognition and attention.

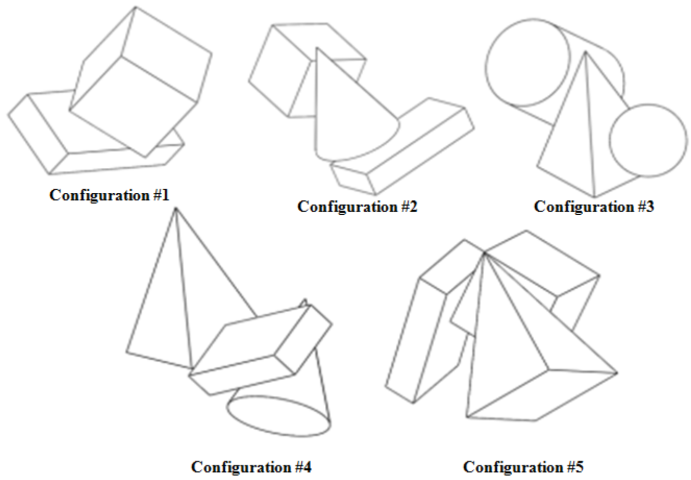

Figure 3 - Graphical configurations presented to students during Enlightenment

Implementation

1. Each configuration was presented to the students for one minute. During this time the students' were encouraged to examine and memorise the image. The students were not allowed to sketch during this time.
2. The image was removed after one minute expired.
3. The students were allowed two minutes to communicate the configuration (Figure 4).
4. The image was then re-shown to the students and they were asked to compare it to their sketch and rate the likeness along a scale (where 1= *'Very Inaccurate'*… 10 = *'Very Accurate'*).
5. When all five exercises were complete, the students were afforded the opportunity to provide any feedback comments. They were also asked to describe how they best remembered the information in addition to describing any difficulties they may have had. All comments were analysed and coded by the researcher.
6. While the activity was taking place, the researcher recorded observations of the students' as they examined and sketched the configurations.
7. The overall activity took around 30 minutes to complete.

Figure 4 - Students engaging in the 'Enlightenment activity'

Results

Analysis of the generated sketches suggested that the students' generally communicated a similar configuration to the target image with the correct type and number of geometric shapes. A selection of students' sketches is presented in Figure 5. It appeared that the students' may have had difficulty in communicating the correct orientation and relationship between the geometries and this was increasingly evident in the third and fourth configurations. Figure 6 illustrates the mean *'likeness'* rating for each configuration, where n = 125. These ratings suggest that the students' struggled with the initial configuration but quickly gained confidence and refined their strategies for the second and third configurations. The ratings for the fourth and fifth configurations were lower and this may have been due to the higher levels of complexity and poorer concentration levels of the students.

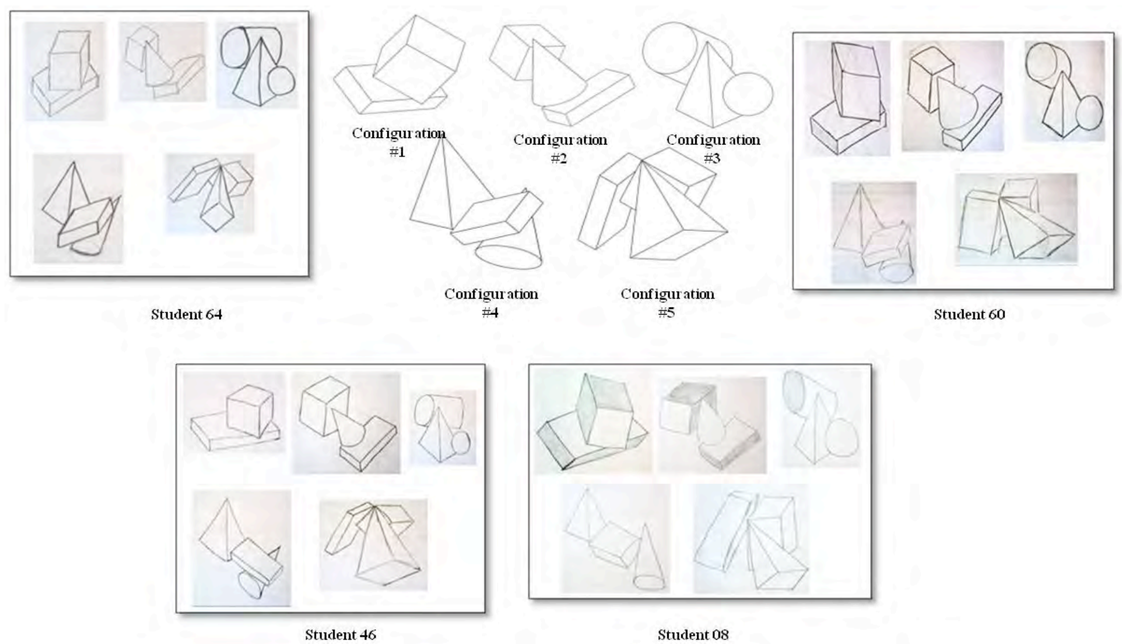

Figure 5 - Selection of sketches for *'Enlightenment'* activity

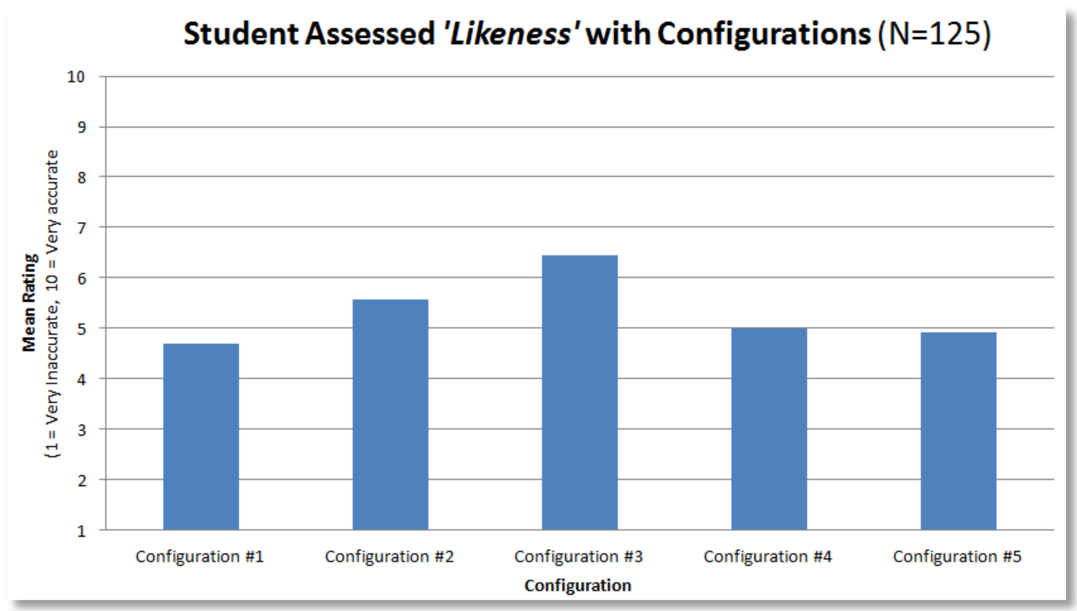

Figure 6 - Student self-assessment of sketches with actual configurations

In order to comprehend how the students formed their visual image of each configuration prior to sketching, it was necessary to examine their feedback. A selection of these comments is presented in Table 1 while all coded comments are illustrated in Figure 7. The majority of students' claimed that they best formed the mental image by *'analysing the relationships'* between the geometries. Interestingly, 4% of students' claimed to have created some sort of a story to visualise the image while 13% of students claimed it was advantageous if they closed their eyes periodically.

The main finding from these data was that the students' tended to incorporate very different strategies when attempting to build visual mental images and the nature of these strategies depended on the individual student and their own preferred style.

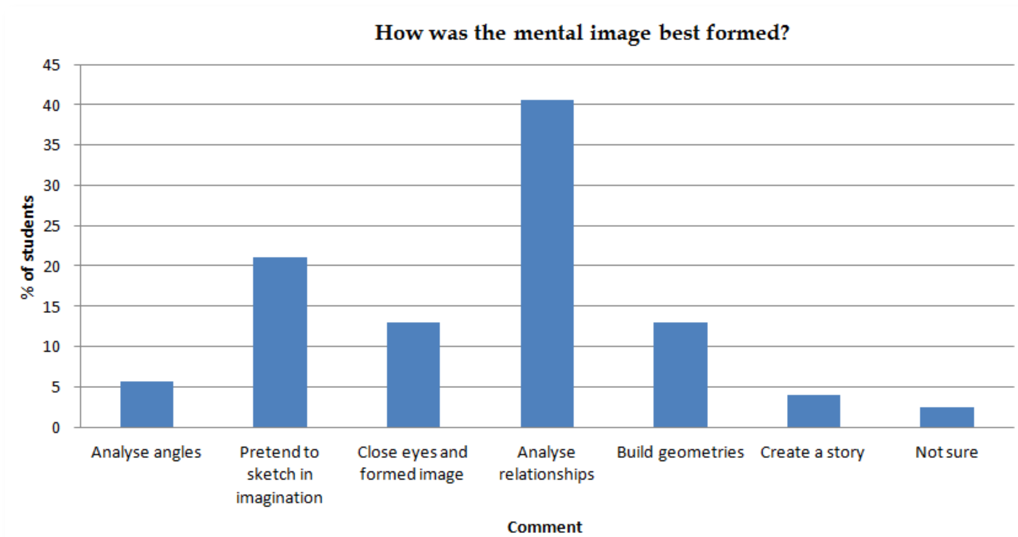

Figure 7 - Student comments for how was image based formed during Enlightenment

Table 1 - Selection of comments about how the image was best formed

	Comment
Student 110	*"Analysing the relationships between geometries. Temporarily removing a shape to aid memory"*
Student 127	*"Focusing on the image and picking a common point all the shapes had and worked from there"*
Student 129	*"From looking at the points where the objects met with each other and focusing on them"*
Student 43	*"By closing my eyes and piecing it together part by part"*
Student 78	*"I pretended to draw the image with my pencil and linking it to other stuff, like for the last one I thought the orientation was a bit like a crows foot"*
Student 23	*"Found a starting object and begin to form the image around it. Relate the other objects to it"*
Student	*"Kept staring at it, remembering where objects started and where they meet.*

133	*Having a few definite points and going with that"*
Student 12	*"By relating intersections as being x-distance from particular features or along certain lines"*

In order to understand what difficulties the students may have had during the activity, it was necessary to examine their feedback. A selection of these comments is presented in

Table **2** while all coded comments are illustrated in Figure 8. The majority of students' claimed that it was difficult to either *"remember the orientation"* of the configuration or *"remember the relationships"* between the geometries. Furthermore, it was apparent that some students found it difficult to concentrate on the last two activities. 9% of students claimed that it was difficult to remember the third shape once they had two drawn.

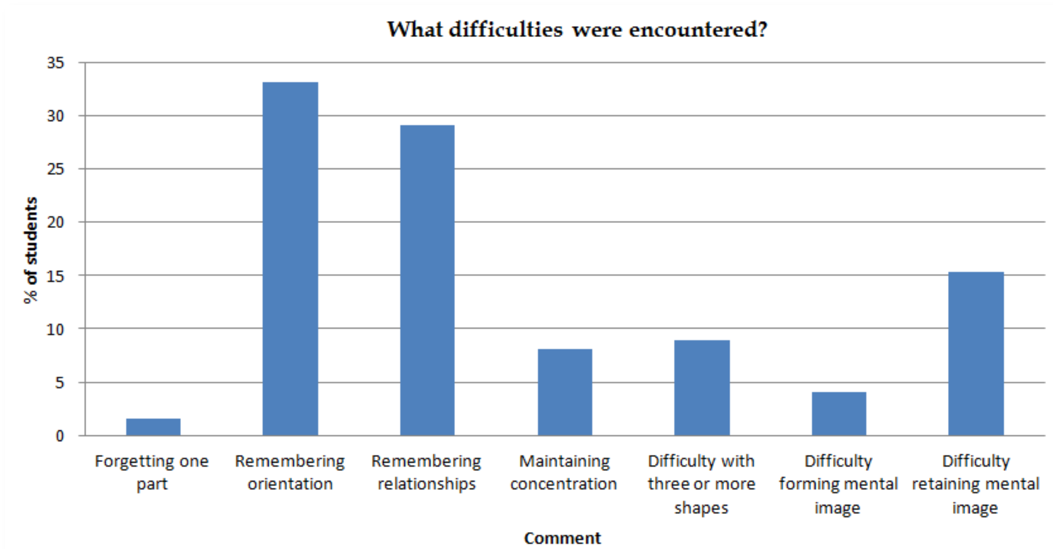

Figure 8 - Student comments for difficulties encountered during Enlightenment

Table 2 - Selection of comments describing difficulties encountered

	Comment
Student 10	*"Remembering the angles the shapes were at"*
Student 130	*"Really hard to picture when screen goes blank, sometimes you just go blank!"*
Student 31	*"If there were three objects, by the time I have two drawn, the third would become vague"*

Student 40	*"Found it hard to remember all three shapes. Two were fine but the third always got me."*
Student 24	*"While drawing, I would eventually lose the image and information I had on the third object I had sketched"*
Student 87	*"Toward the fourth and fifth activity struggled with concentration. Found it hard to place shapes in right positions"*
Student 37	*"Short term memory. I have always found that I have a very poor short term memory"*
Student 72	*"Thinking I had it visualised and then the orientation of one or two objects blanked on me"*

The students' general feedback comments were analysed and coded. These are illustrated in Figure 9 while a selection of comments is presented in Table 3. The majority of students stated that the activity was *"beneficial and worthwhile"* or that they *"enjoyed the challenge"*. A small number of students' claimed that they *"didn't see the relevance"* of the activity while a large number of students commented on the cognitive challenge and relevance of the activity to the development of their graphical skills.

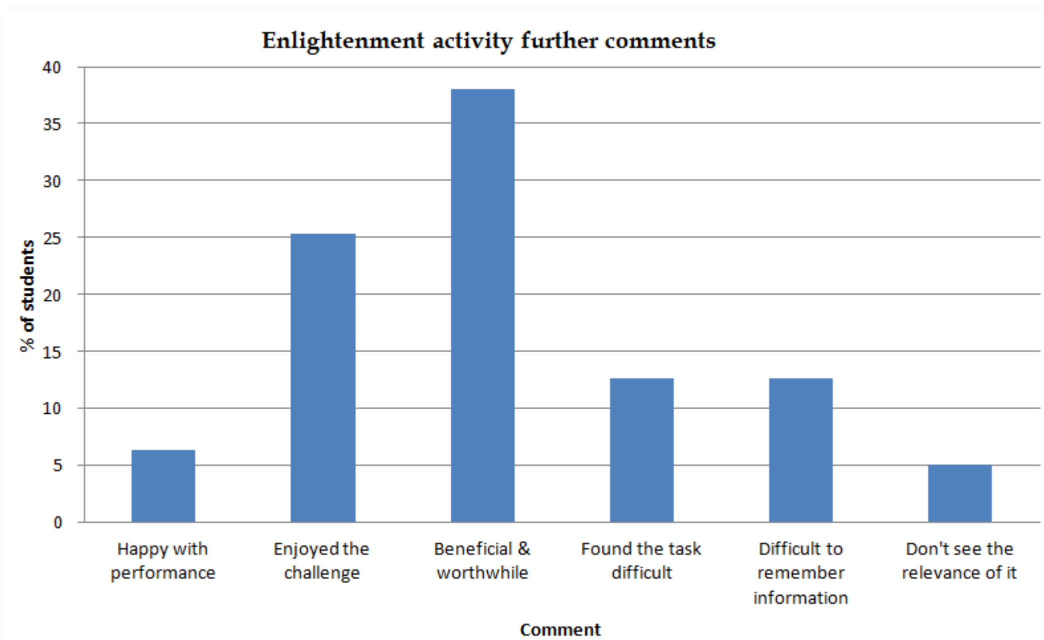

Figure 9 - Student feedback comments for Enlightenment activity

Table 3 - Selection of feedback comments regarding the overall activity

	Comment
Student 102	*"The name of the activity was deceiving, didn't find it that enlightening. Give me interpenetration or road geometry any day"*
Student 104	*"Good activity but can confuse the brain. As the tasks went on the challenge got harder and this was difficult to do. But it was a good cognitive exercise"*
Student 127	*"First image was poor but see the improvement as I went on and completed the other activities"*
Student 40	*"I found this very difficult overall. I felt like I was afraid to express myself and I don't know why that is."*
Student 58	*"I think that if I had carried out this task at a better time during the day I could have done better on them as I felt as if my concentration is very bad this morning"*
Student 86	*"Very good challenging activity"*
Student 21	*"This is a good exercise and I could see its benefits in interpenetration questions"*
Student 66	*"This is very new to me so I thought I did well. Also, I am now starting to understand the reasons for what we have been doing – making a visual image – learning how to learn"*
Student 76	*"This activity was really good as it made you be more fluid in terms of trying to discover what the shape was and re-create it in your mind"*
Student 91	*"Fun exercise. Would like to teach in a school"*

The data were further analysed in order to establish the relationship between the different strategies employed, difficulties encountered and the *'likeness'* ratings for each configuration. In general it was found that students who analysed the relationships between geometries tended to rated their images higher while also claimed it was sometimes difficult to maintain concentration. Students' who rated *'likeness'* lower generally tended to employ strategies such as opening and closing eyes and tried to make mathematical sense of the geometry. These students generally tended to find it difficult to remember the third shape and forgot critical information.

Discussion

The strengths of the research study described in this paper lie in the design of the *'Enlightenment'* activity and how it was informed by research literature in human cognition and memory. In addition to this, the activity forms a key stage within the empirically validated model of activities which promotes the development of sketching expertise (Lane, 2011).

The rich nature of qualitative data and observational records gathered during the activity provide an insight into the various strategies employed by students while undertaking the memory based activities and forming the visual mental images. The broad range of strategies for creating mental images such as; creating a story, opening and closing eyes, drawing in space and mathematical reasoning, highlight the importance of facilitating students' meta-cognitive development.

The comments provided by the students' in relation to the difficulties encountered and the *'likeness'* ratings, indicated that the activity was pitched at a cognitively challenging level. This higher level of difficulty is necessary in order to facilitate the progression away from relying on visual scaffolds where mental images can be easily refreshed.

The *'Enlightenment'* activity has implications across all facets of graphics education where problem solving skills are required. Developing the ability to effectively utilise the *'visuo-spatial sketchpad'* of short-term memory promotes the formation of *'chunks'* of visual mental information to be stored in long term memory. This is becoming increasingly important within graphics education where students are now expected to develop the necessary attributes to think creatively and synthesise large amounts of information while solving graphical problems.

Finally, the findings from this study highlight that students find it very challenging to visualise and communicate geometry which is presented in an unconventional orientation. Perhaps students are somewhat conditioned to visualise regular geometries in conventional orientations (such as isometric or pictorial) and that they find it cognitively challenging to create, retrieve and communicate these visual mental images in unconventional forms. This further highlights the important role of developing students' ability to utilise their *'visuo-spatial sketchpad'* through activities such as *'Enlightenment'* and this has potential to enhance their ability to effectively carry out complex cognitive modelling tasks.

References

Baddeley, A. (1998). Recent Developments in Working Memory. *Current Opinion in Neurobiology, 8*, 234-238.

Borst, G., Kosslyn, S.M. (2008). Visual mental imagery and visual perception: Structural equivalence revealed by scanning processes. *Memory & Cognition, 36*(4), 849-862.

Bruyer, R., Scailquin, J. (1998). The visuospatial sketchpad for mental images: Testing the multicomponent model of working memory. *Acta Psychologica, 1998*, 17-36.

Ericsson, K. A., Kintsch, W. . (1995). Long-term working memory. *Psychological Review, 102*(2), 211-245.

Finke, R. A., Shepard, R. N. (1986). Visual functions of mental imagery. In K. R. Boff, Kaufman, L., Thomas, J.P. (Ed.), *Handbook of Perception and Human Performance* (pp. 1-55). New York: Wiley - Interscience.

Fish, J., Scrivener, S. (1990). Amplifying the Mind's Eye: Sketching and Visual Cognition. *Leonardo, 23*(1), 117-126.

Krupa, D. J., Thompson, J.K., Thompson, R.F. (1993). Localization of a Memory Trace in the Mammalian Brain. *Science, 260*(5110), 989-991.

Lane, D. (2011). *Developing Sketching Expertise within Technology Education.* University of Limerick, Limerick.

Lane, D., Seery, N., Gordon, S. (2009). The Understated Value of Freehand Sketching in Technology Education. *Engineering Design Graphics Journal, 73*(3), 13-22.

Lane, D., Seery, N., Gordon, S. (2010). *Utilising Sketching to Amplify Concept Driven Competencies*. Paper presented at the D&T Ideas Worth Sharing.

Nilsson, L. G. (2003). Memory Function in Normal Aging. *Acta Neurologica Scandinavica, 107*(0), 7-13.

Stillings, N. A., et al. (1995). *Cognitive Science: An Introduction*. London: MIT Press.

Storer, I. (2008). Reflecting on professional practice : capturing an industrial designer's expertise to support the development of the sketching capabilities of novices. *Design and Technology Education: An International Journal, 10*(1), 19.

Tulving, E. (1987). Multiple Memory Systems and Consciousness. *Human Neurobiol, 6*, 67-80.

Tulving, E. (1991). Concepts of human memory. In L. R. Squire, et al (Ed.), *Organization and locus of change* (pp. 3-32). New York: Oxford University Press.

vanGorp, W. G., Altshuler, L., Mintz, J. (1999). Declarative and Procedural Memory in Bipolar Disorder. *Biological Psychiatry, 46*(4), 525-531.

An Overview of Tests of Cognitive Spatial Ability

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Abstract

There are a wide variety of tests available to assess different aspects of cognitive spatial ability. Tests of 3-dimensional rotation are often used in assessing the spatial abilities of engineering students. However, the ability to mentally rotate objects in three dimensions is only part of a complex array of spatial abilities that students may use when creating the mental models necessary for success in engineering design, problem solving, and other coursework in the STEM fields. This paper will describe a variety of tests and discuss which aspects of cognitive spatial ability they are designed to measure. Having an understanding of a wider range of assessment tools could potentially improve the quality of research in the engineering fields especially when considering comparisons of student success across the STEM fields based on cognitive spatial ability.

Introduction

Specialized visualization abilities are necessary for success in the different areas of STEM education. The ability to mentally rotate objects is important in engineering fields and tests of 3-dimensional rotation, such as the Purdue Spatial Visualization Test by Guay (1976) and the Mental Rotation Test by Vandenberg and Kuse (1978), are often used in assessing the spatial abilities of engineering students.

Scientific visualization, graphing, and using multiple representations are important in mathematics and science teaching (Thomas, 1995).

In chemistry, closure flexibility, the ability to identify patterns in the midst of distracting stimuli, is needed for the identification of similarities and differences between complex molecular structures. And 2D mental rotations, similar to those assessed with card rotation tests, are useful in the identification of isomers (Wu & Shah, 2004).

In physics, tests of speeded mental rotation have been used to study the correlation between visualization ability and accurately solving kinematics problems (Kozhevnikov, Motes & Hegarty, 2007).

Selected Tests of Cognitive Spatial Ability

According to Reio, Czarnolewski, and Eliot (2004), some tests of spatial ability have relationships with everyday activities which may make these tests more appropriate for assessing the spatial abilities of students with different academic backgrounds and pretest experiences. These tests include the Card Rotation Test (French, Ekstrom, & Price, 1963); the Hidden Figures Test (Ekstrom, French, Harman, and Dermen, 1976); the Gestalt Completion Test (Eliot & Czarnolewski, 1999); and the Visual Memory Test (Stumpf, 1992). Following are some sample images of these tests and others that assess different aspects of spatial visualization ability.

The Card Rotation Test (French, Ekstrom, & Price, 1963) is a 4 minute timed test with 112 items and measures 2-dimensional orientation and rotation. Given the object on the left, the subject must check whether the object on the right is the same (S) or different (D) (Figure 1).

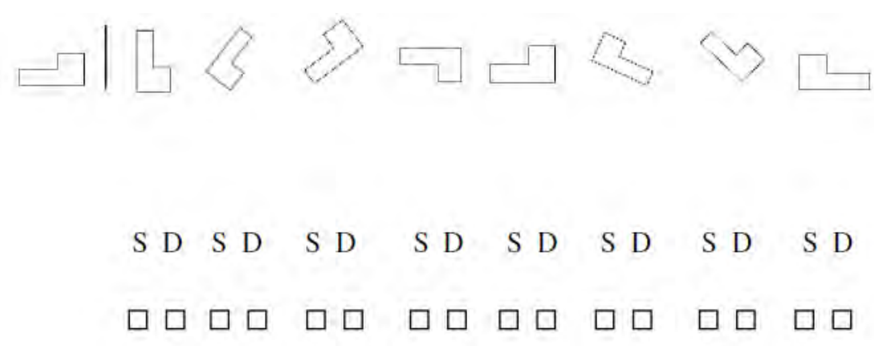

Figure 1. Card Rotation Test example

The Hidden Figures Test (Ekstrom, et.al., 1976) measures flexibility of closure. It is a 5 minute timed test with 12 items. The subject must select which one of the set of five geometric shapes is hidden in the figure below the set (Figure 2).

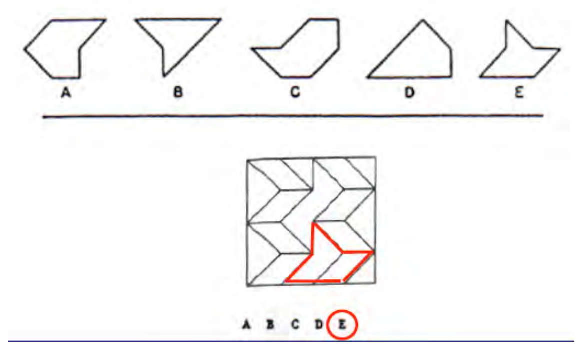

Figure 2. Hidden Figures Test example

The Gestalt Completion Test (Eliot & Czarnolewski, 1999), a 5 minute 24 item test, measures speed of closure, which is the ability to construct a whole item from incomplete material (Figure 3). There are multiple versions of this test available in different formats by different authors.

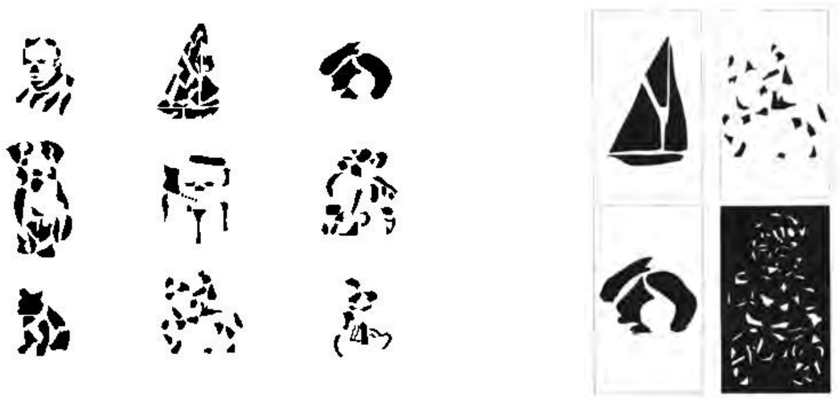

Figure 3. Gestalt Completion Test example

The Revised Minnesota Paper Form Board Test (Likert & Quasha, 1995) is a 20 minute timed test with 64 items that measures 2D spatial visualization. In this test, subjects are shown geometric shapes and then must select which one of the five completed figures can be made from the shapes (Figure 4).

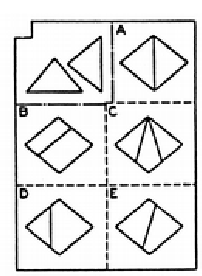

Figure 4. Revised Minnesota Paper Form Board Test example

The Raven's Progressive Matrices test (Raven, 1938) measures abstract reasoning using spatial components (Figure 5). There are multiple iterations of the test including the Colored Progressive Matrices and Advanced Progressive matrices.

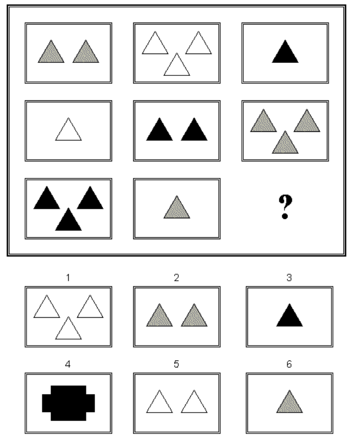

Figure 5. Raven's Progressive Matrices test example

The Punched Holes Test (Ekstrom, et.al., 1976) is a timed 3 minute 10 item test that measures spatial ability. In this test, the image on the left shows a sequence of folds in a piece of paper, through which a hole or set of holes is punched. The subject must choose which of the five images on the right would correspond with the unfolded paper (Figure 6). Tests of similar format are also referred to as paper folding tests.

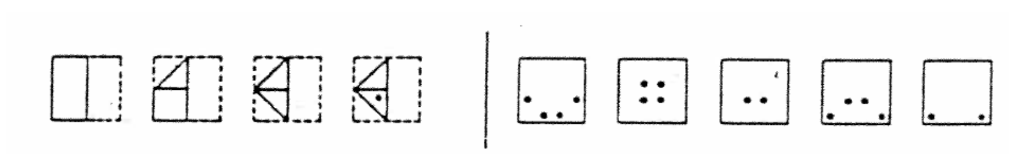

Figure 6. Punched Holes Test example

The Surface Development Test (Ekstrom, et.al., 1976) is a test of spatial ability that requires the subject to create a mental image of the object on the right built from the flat pattern on the left. Then they must determine which letters on the 3D image correspond with the numbers on the flat pattern (Figure 7).

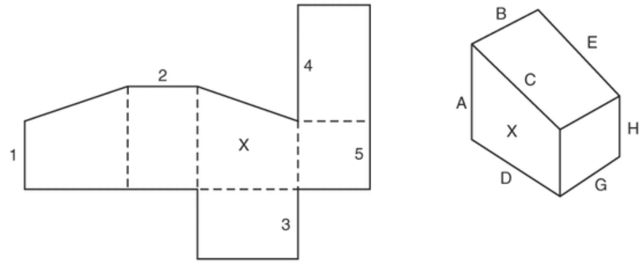

Figure 7. Surface Development Test example

Reliability and Validity of Selected Tests

Card Rotation Test

Reliability: Kuder-Richardson coefficient of .72

Gestalt Completion Test

Reliability: Spearman-Brown correlation correction yields a coefficient of .68

Hidden Figures Test

Reliability: Kuder-Richardson coefficient of .76

Revised Minnesota Paper Form Board Test

Reliability: Kuder-Richardson coefficient of .61

Raven's Progressive Matrices Test

Reliability: Test-retest reliability coefficients range from .76 to .91.

Punched Holes Test

Reliability: Kuder-Richardson coefficient of .68

Surface Development Test

Reliability: Kuder-Richardson coefficient of .84

(Goldman, Osborne, & Mitchell, 1996)

Discussion

The tests described here are only a few of the many tests that that assess cognitive spatial ability. In the research for this paper over fifty different tests were found, some of which are derivations of the above tests, and some of which are completely different in format and scope. The spatial abilities measured in the tests investigated ranged from 2D and 3D mental rotations, to environmental scanning, speeded visual exploration, flexibility and speed of closure, long-term spatial location memory and measurement of space. Many of the tests have similar levels of reliability and validity so the choice of test would depend on which particular visualization skills are to be assessed. And these skills may be field specific because as noted earlier in the paper, different STEM fields require different visualization abilities for student success.

Because there is often significant overlap in the core requirements for study in the STEM fields, especially among courses in mathematics, physics, or chemistry and research across disciplines is becoming more widespread, using multiple or alternate assessments should be considered. More research is planned to investigate additional tests and categorize them based on what they assess and how they may be appropriate to specific STEM disciplines.

Some of the questions that have arisen from this initial research include:

- Would the remediation that has resulted in increased scores on tests of 3D mental rotation like the PSVT also improve the scores on tests that assess 2D rotation, environmental scanning, speed of closure and so on?

- Would the improved GPAs in STEM courses for engineering students who received remediation based on 3D rotations cause a similar gain for students enrolled in majors such as mathematics, chemistry, or physics?
- If engineering students are having problems in their mathematics, chemistry, or physics courses, would assessing their visualization abilities with tests more specifically targeted to skills in those fields be advantageous?

References

Ekstrom, R. B., French, J. W., Harman, H. H. & Dermen, D. (1976). *Manual for kit of factor-referenced cognitive tests*. Princeton, NJ: Educational Testing Service.

Eliot, J., & Czarnolewski, M. Y. (1999). A composite Gestalt completion test. *Perceptual and Motor Skills, 89*, 294-300.

French, J., Ekstrom, R., & Price, L. (1963). *Kit of reference tests for cognitive factors*. Princeton, NJ: Educational Testing Service.

Goldman, B. A., Osborne, W. L., & Mitchell, D. F. (1996). *Directory of unpublished experimental measures*. Washington, DC: American Psychological Association.

Guay, R. B. (1976). *Purdue spatial visualization test – visualization of rotations*. West Lafayette, IN. Purdue Research Foundation.

Kozhevnikov, M., Motes, M., & Hegarty, M., (2007). Spatial visualization in physics problem solving. *Cognitive Science*, 31, 549-579.

Likert, R., & Quasha, W. (1995). *Revised Minnesota paper form board test manual (2nd ed.)*. San Antonio, TX: The Psychological Corporation.

Olson, D. M., & Eliot, J. (1986). Relationships between experiences, processing style, and sex-related differences in performance on spatial tests. *Perceptual and Motor Skills*, 62, 447-460.

Raven, J. C. (1938). *Progressive matrices: A perceptual test of intelligence*. London: H.K. Lewis.

Reio, T. G., Czarnolewski, M., & Eliot, J. (2004). Handedness and spatial ability: Differential patterns of relationships. *Laterality*, 9 (3), 339-358

Stumpf, H. (1992). *A test of visual memory*. Baltimore, MD: Center for Talented Youths.

Thomas, D. A. (Ed.) (1995). *Scientific visualization in mathematics and science teaching*. Charlottesville, VA: AACE.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills*, 47, 599–604.

Wu, H., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education, 88* (3), 465-492.

Using First Year Engineering Graphics Course for Student Outcomes and Assessment

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Abstract

This paper shows how a first year course in engineering graphics has been used for attaining ABET student outcomes and assessment, as well as to learn lessons for continuous improvement. The following student outcomes were used: (d) ability to function on multidisciplinary teams, (g) ability to communicate effectively, and (k) ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. For each student outcome items were selected from the course syllabus that address the student outcome, as well as the items used to evaluate if the student outcomes had been attained. The course objectives included, among others, helping students understand the role of engineering graphics in the engineering design process, understanding and applying the engineering graphics language and tools of the engineer, creating design sketches using pencil and computer, using reverse engineering to create working drawings, detail and assembly drawings. Students were taught freehand sketching, visualization, mechanical drafting, CAD using AutoCAD, Creo Elements/Pro Engineer and SolidWorks. They were then organized into teams and assigned to choose individual team projects on reverse engineering of mechanisms that had design intent. Students were tasked to make oral presentations to communicate the design intent. These presentations can be in the form of power point slides or equivalent, or posters. Student assignments as well as team projects were graded by the course instructor. Students also carried out peer evaluations of team members. Direct and indirect assessments were used to evaluate student outcome attainment. The level of attainment of the student outcomes was compared to the target levels and action steps identified for further improvements.

Introduction

The objectives of this paper are:

- To demonstrate how Engineering Graphics (EG) can be used for attaining
    - ability to function on multidisciplinary teams;
    - ability to communicate effectively;
    - ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

- To learn lessons for continuous improvement.

Literature Review

Teamwork has always been a common element in engineering learning. Two learning outcomes result from teamwork: outcomes relative to course content (product outcomes), and outcomes relative to team skills and participation (process outcomes). Engineering faculty is generally comfortable in enhancing learning in the content area. However, enhancing learning in the team skills is quite often unfamiliar (Agoki, Clark, Behnke, and Lee, 2007). To be cooperative a group of students require positive interdependence, promoting each other's learning and success, holding each other personally and individually accountable to doing a fair share of work, appropriately using interpersonal and small group skills needed for cooperative efforts to be successful, and processing as a group how effectively members are working together (Smith, 1995).

The freehand sketches and the Pro Engineer drawings demonstrated that a mixed group of students (college freshmen, sophomores, seniors; high school and home schooling) who have no drafting experience prior to enrolling for an engineering graphics course can learn and develop basic skills in graphics communication within an academic semester. Also, through this course students demonstrated that they could work in a team and subgroups to accomplish a task/project provided they get clear instructions of what is expected of them, and that they have effective leadership by one of them and have mastered the basics of engineering graphics (Agoki, Clark, Behnke, and Lee, 2007).

The following lessons with respect to skills development in technical writing, presentation, and teamwork were learned (Agoki, Clark, Behnke, and Lee, 2007):

- That the instructor and the client should be readily available for consultation.
- That when students are assisted, it facilitates them to complete assignments; even the complex ones.
- The instructor and the student Project Team Leader should balance work distribution and cater for the best students as well as slow learners.
- Incorporating a real life experience helps to bring course material to reality and aids in skills development and affords an opportunity for students who are engineers-in the-making to have a foretaste of how engineering teams work in real life situations. Such experiences help to concretize concepts that would otherwise remain abstract.
- Pizza helps create a hospitable working environment and helps to motivate students in their class work and completion of assignments.
- Students will complete assignments and do their best when they know that the work will contribute to the final grade.

- There has to be fallback measures in case students do not complete work that has due dates promised to the client. Delays in delivery can cause delays in shipment with severe financial implications.

As part of the evaluation students made the following comments with respect to the course Engineering Graphics: “The class teaches good teamwork, very good team work on the whole” (Agoki, Ng, and Johnson, 2007). Agoki, Ng, and Johnson (2007) concluded that first year courses, Introduction to Engineering and Engineering Graphics, are excellent vehicles for initiating students into engineering and developing their skills in technical writing, oral communication, team building, creativity, analysis and synthesis in the overall engineering design process; through real life projects.

Andrews University has stipulated that “No course with a grade below C- may count toward a major or minor” (Andrews University, 2011-12), and the following target levels have been set for the Engineering Program for the attainment of student outcomes: 85-100% Good, acceptable; 70-84% Fair, improve; <70% Poor, unacceptable (Andrews University Engineering Program, 2009).

Methodology

For each Student Outcome (SO) items were selected from the course syllabus that addressed the SO, as well as the items used to evaluate if the SOs had been attained. The items from the syllabus that addressed SOs included team projects using reverse engineering problems, course objectives, assignments, exercises and labs. The items used to evaluate if the SOs had been attained included the instructor’s direct assessment of the team projects, students’ peer evaluation of team members; oral presentation of team projects, models, drawings, and posters; examinations on visualizations, AutoCAD, SolidWorks and Creo Elements/Pro Engineer.

The course objectives included, among others, helping students understand the role of engineering graphics in the engineering design process, understanding and applying the engineering graphics language and tools of the engineer, creating design sketches using pencil and computer, using reverse engineering to create working drawings, detail and assembly drawings.

Students were taught freehand sketching, visualization, mechanical drafting, CAD using AutoCAD, Creo Elements/Pro Engineer, and SolidWorks. They were then organized into teams and instructed to choose individual team projects on reverse engineering. The students were required to identify the design intent in the product. For each project, the following was required: disassembling, measuring, and sketching each part; creating 3-D models or engineering drawings of each nonstandard part, with dimensions; specifying standard parts, using engineering catalogs; creating an assembly drawing with parts list; creating a written report that summarized the project, listing the strengths and weaknesses of the product they reverse engineered, comments on the serviceability of the product, recommended changes to the design, with special reference to Design For Manufacturability (DFM) principles (Bertoline, Wiebe, Hartman and Ross, 2011).

Students were further tasked to make oral presentations to communicate the design intent. These presentations could be in the form of power-point slides or equivalent, or posters.

Student assignments as well as team projects were graded by the course instructor. Each student peer evaluated a team member using the evaluation instrument developed by the instructor. Each student completed an indirect assessment to evaluate how well they thought they had attained the SO. Both the direct and indirect assessments were used to evaluate SO attainment. The level of attainment of the SOs was compared to the target levels that had earlier been set and action steps were identified for further improvements.

Results and Findings

Peer Evaluation of Ability to Function in Multidisciplinary Teams: Below is a report summary of 31 respondents out of a class of 36 who worked in groups of 3 to 4 students to develop the ability to function in multidisciplinary teams. Table 1 presents the team member knowledgeability and technical competence, Table 2 shows the individual team-member characteristics, Table 3 gives the recommendations about the team member on the project, Table 4 summarizes the results of the positive experience with the team member on the project, and Table 5 displays the results of the negative experience with the team member on the project. Figure 1 presents the results of the peer evaluation of team-member characteristics. Figure 2 shows the comparison of the grades of peer versus instructor assessment of the team projects.

Table 1: Team member knowledgeability and technical competence

Level / Performance Indicator	Below Average 2 (% of Class)	Average 3 (% of Class)	Above Average 4 (% of Class)	Superior 5 (% of Class)
Knowledgeable/ Technically Competent	3%	13%	55%	29%

Table 2: Individual team member characteristics

Level / Characteristic	Below Average 2 (% of Class)	Average 3 (% of Class)	Above Average 4 (% of Class)	Superior 5 (% of Class)
Creative	0	20%	48%	32%
Responsible	0	13%	39%	48%
Decision maker	0	19%	55%	26%
Organized/Prompt/ Dependable	3%	10%	32%	55%
Valuable/loyal	0	6%	39%	55%
Capable of leadership	3%	23%	35%	39%
Friendly	3%	0	29%	68%
Honest/Reliable	0	0	39%	61%
Initiative & Drive	3%	6%	32%	59%

Table 3: Recommendations about team member on the project

Response / Recommendation	NO (% of Class)	YES (% of Class)	Target Level (%)	Remarks on Achievement
Pay Raise	10	90%	85-100	Good, acceptable
Management Position	26	74%	70-84	Fair, improve
Serve with Again	10	90%	85-100	Good, acceptable

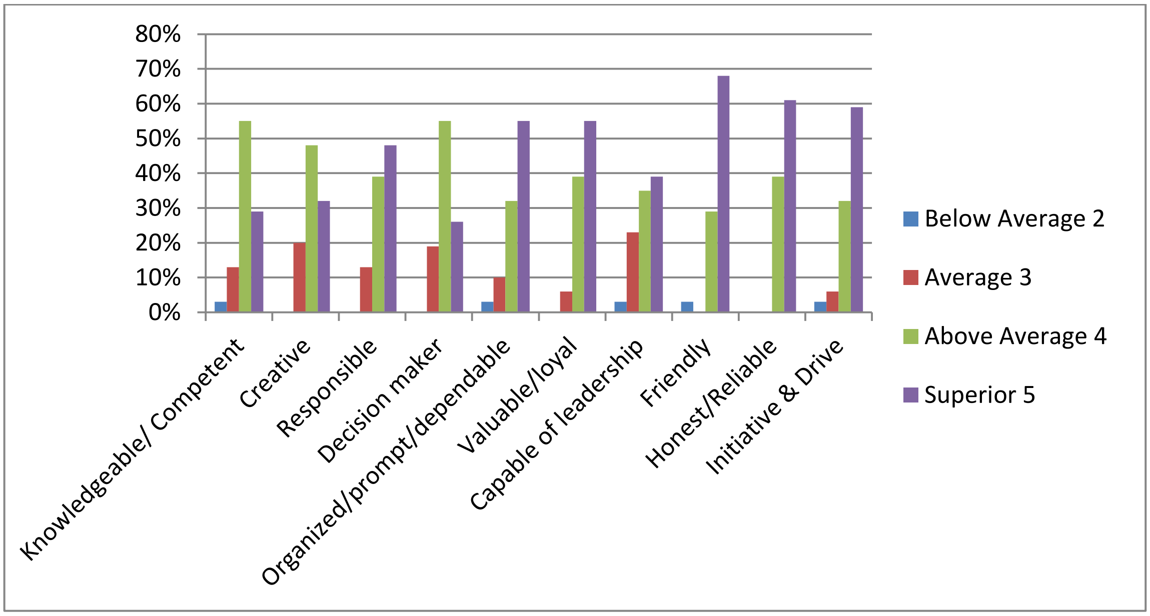

Figure 1: Peer evaluation of team members' characteristics

Table 4: Results of positive experience with team member on the project

Evaluation / Positive Experience	% of Class	Target Level (%)	Remarks on Achievement
Medium to High Pay Raise Level	87	85-100	Good, Acceptable
Warm	94	85-100	Good, Acceptable
Energetic to Indifferent	100	85-100	Good, Acceptable
Compatible	81	70-84	Fair, Improve
Enjoyable/Neutral to work with	100	85-100	Good, Acceptable
Open minded/Flexible	93	85-100	Good, Acceptable
Mature and Professional/Showing Potential	100	85-100	Good, Acceptable

Table 5: Results of negative experience with team member on the project

Evaluation / Negative Experience	% of Class	Target Level (%)	Remarks on Achievement
Domineering	19	16-30	Fair, improve
Low pay raise	13	0-15	Good, acceptable
Opinionated	7	0-15	Good, acceptable
Cold	6	0-15	Good, acceptable

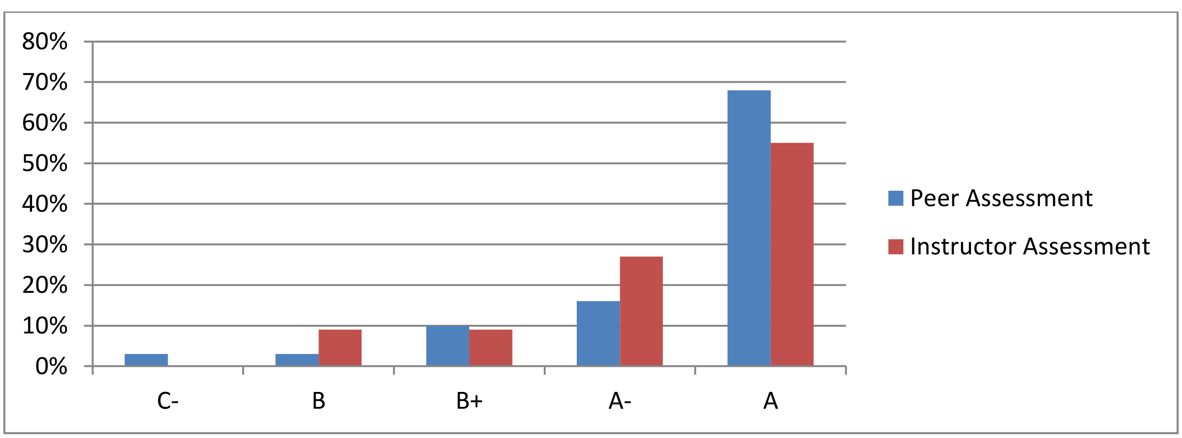

Figure 2: Comparison of grades of peer versus instructor assessment of team projects

The team members provided the following comments about working in multidisciplinary teams:

- "Great partner, teammate spent a lot of time working on the project and was always willing to give 100%."
- "Was an excellent partner, enjoyable to work with, contributed fairly, and had excellent communication skills."
- "Great teammate, good knowledge, wants to participate, really enjoyed working with him, had good ideas."
- "Seemed willing to participate but rarely took the initiative to do something (anything)."
- "Should probably try to communicate with group to move together as a unit."

As overall assessment, 100% of the team projects obtained a grade of "B" or above. One student did not have a teammate. The actions required included enforcing requirement that all students work in multidisciplinary teams, and addressing students' comments above; particularly those that were negative with a view to mitigating them whilst enhancing and strengthening the positive ones.

Ability to Communicate Effectively: Figure 3 displays per cent of class of the instructor's assessment of students' ability to communicate orally, using drawings and to communicate the engineering design intent. Team projects were graded by team members as well as the instructor and subsequently used to assess the attainment of the ability to communicate effectively. Each student was required to make an oral presentation of the role they played in the team project. The oral presentation together with the drawings and models were used to assess the achievement of this outcome for each student. The results of the instructor's direct assessment of the team projects for the 32 students are detailed below. The students' ability to communicate orally - using drawings and models to communicate the engineering design intent - was evaluated.

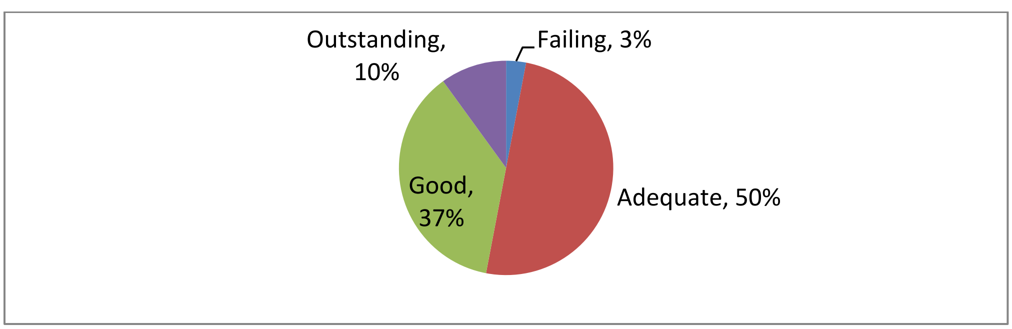

Figure 3: Instructor's assessment of students' ability to communicate orally, using drawings and to communicate the engineering design intent

Overall assessment indicated that:

- 97% of students were able to communicate effectively what they did in their team projects.
- One student did not communicate orally.
- Some groups did not effectively use freehand sketching on their team projects.
- 100% of the team projects obtained a grade of B and above.

The action required was identified to be: To ensure that all students communicate effectively the role they played in the team project and make oral presentation as instructed.

Ability to Use the Techniques, Skills, and Modern Engineering Tools Necessary for Engineering Practice: The results from 32 students who responded are detailed below. Figure 4 gives the students' self-assessment of their engineering graphics skills before and after taking the course. Figure 5 summarizes the students' self-assessment of their AutoCAD/Creo Elements Pro Engineer/SolidWorks skills before and after taking the course, and Figure 6 shows the comparison of the instructor's direct assessment to the students' indirect assessment of their overall grade.

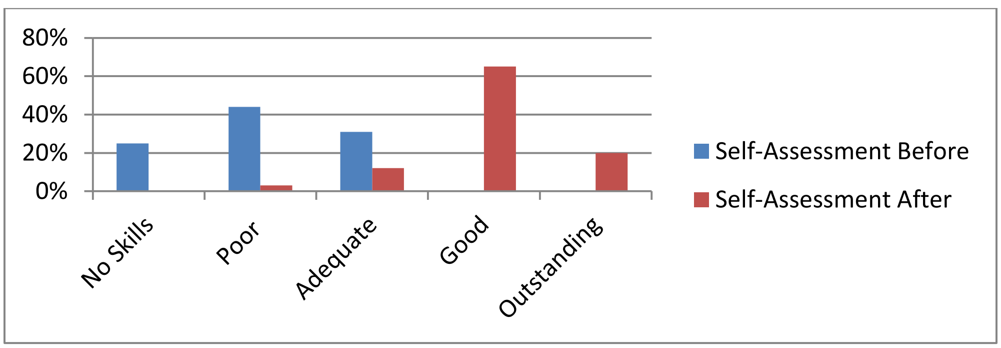

Figure 4: Students' self-assessment of their engineering graphics skills before and after taking the course

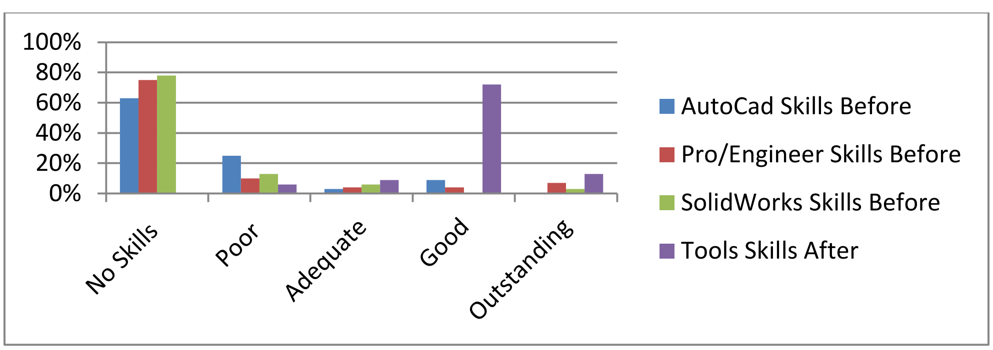

Figure 5: Students' self-assessment of their AutoCAD/Creo Elements Pro Engineer/SolidWorks skills before and after taking the course

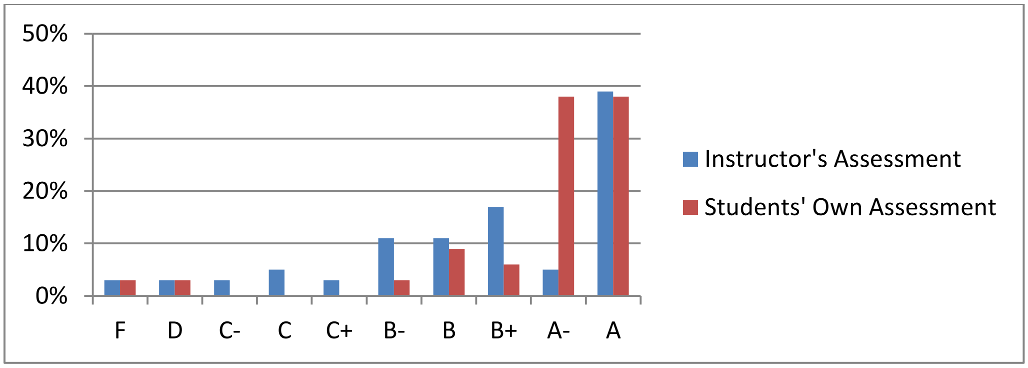

Figure 6: Comparison of instructor's direct assessment to the students' indirect assessment of overall grade

Discussion

Table 1 and Figure 1 reveal that 97% of the class was peer evaluated to have knowledgeability and technical competence ranging average to superior. This is a positive reflection on the attainment of product outcome (course content). Table 2 and Figure 1 show that for creativity, responsibility, decision making, valuability/loyalty, and honesty/reliability - as individual team-member characteristics – the peer evaluation indicated that 100% of the class attained average to superior; whereas for organization/promptness/dependability, capability of leadership, and initiative plus drive 97% of the class members were judged to be average to superior. Again, these results on team-member characteristics reveal that the team building ingredients were brought to the team project to help in team building, which in turn reflects positively on the attainment of the process outcome. Table 3 reveals that team building was attained as 90% of the class indicated that they would serve with their team members again. In terms of management skills, only 74% were recommended by peers for management positions. This is an aspect that should be focused on for improvement. From Table 4 it can be said that the class had a positive experience in the team projects as shown by the peer evaluation. However, compatibility is an issue that requires consideration for improvement when organizing teams. Table 5 reveals the negative experiences, as peer evaluated, to be "domineering", not deserving "pay raise", "opinionated", and "cold". Using the target levels set, these negative experiences were well within range except for the "domineering" category that requires improvement. Indeed, the target level should be reviewed with a view to minimizing these negative experiences that could adversely impact team building.

The overall grade for the team projects can be used as a proxy measure for the attainment of SO "ability to function on multidisciplinary teams". Using peer and instructor assessment all team projects obtained a grade of C- and above (Figure 2). According to Andrews University grade requirement all team projects passed satisfactorily with respect to SO (d), except for the project carried out by only one student (one-member team not being allowed) . For future team projects all students will be required to be in a team consisting at least two members.

For SO “ability to communicate effectively,” Figure 3 shows that according to the instructor’s direct assessment 97% of the students were able to communicate effectively. This attainment is within the 85-100% target level which is “Good, acceptable”. Although one student did not communicate orally, he/she was able to communicate using other means, particularly using EG. The groups that did not effectively use freehand sketching on their team projects lost points on their team project grade as this had been stated as a requirement to enhance communication.

From Figures 4, 5 and 6 the instructor’s and the students’ own assessments indicate that a majority of students enroll for EG with no/poor skills and only a small percentage (less than 10%) say that they come with adequate EG skills with respect to SO “ability to use the techniques, skills and modern engineering tools necessary for engineering practice”. After taking the EG course the instructor’s and students’ own assessments reveal that 94% of the class attained a grade of C- and above; thus meeting the target level of “85-100% Good, acceptable”. The need to expose students to AutoCAD, Creo Elements/Pro Engineer, and SolidWorks has been debated in terms of whether this is not sacrificing depth and proficiency. However, there are arguments in favor of this practice as these three software tools are the ones commonly used in industry and different faculty members have preferences when it comes to modeling for other courses such as machine design, manufacturing, and finite element methods.

A number of lessons have been learned with respect to assessment rubrics, targets, data collection and analysis, among others. These lessons are:

- There is need to have clear and concise rubrics for assessing the SOs. The rubrics should clearly show the performance indicators as well as the proxy measures being used for assessment. These need to be refined continuously.
- There needs to be a basis and rationale for targets set for evaluating the attainment of SOs. Once the targets are set, they need to be reviewed and revised for continuous improvement.
- The assessment data collected need to be analyzed in a simple but clear fashion to facilitate the determination of whether or not the SOs have been attained and to what degree, as well as helping in pointing to the necessary action for improvement.

Conclusions

In conclusion, this paper has amply demonstrated that the First Year Engineering Graphics Course can indeed be used for the assessment of the attainment of ABET Student Outcomes (d) ability to function on multidisciplinary teams, (g) ability to communicate effectively, and (k) ability to use techniques, skills, and modern engineering tools necessary for engineering practice as detailed in the paper; and a number of valuable lessons regarding rubrics, attainment targets, and assessment data analysis have been learned for continuous improvement. Further work needs to be directed toward the development of rubrics for assessing SOs, the development of the basis for performance targets, and the development of analytical tools for assessment data.

References

Agoki, G.S, Clark, A., Behnke, S., Lee, B.E. (2007), *Skills Development: Technical Writing, Presentation, and Teamwork through Engineering Graphics*. 37th ASEE/IEEE Frontiers in Education Conference, pp. T3B-20, 21; Milwaukee

Agoki, G.S, Ng, B-C, Johnson, R.L. (2007), *Development of Communication Skills and Teamwork amongst Undergraduate Engineering Students*. 37th ASEE/IEEE Frontiers in Education Conference, pp. F3B-13-19; Milwaukee

Andrews University (2011). *2011-12 Bulletin*, p. 37; Berrien springs

Andrews University (2009). *Engineering Program (BSE) Focused Report*, pp. 14-25; Berrien Springs

Bertoline, G.R., Wiebe, E.N., Hartman, N.W., and Ross, W.A. (2011) *Fundamentals of Graphics Communication, 6th ed.* McGraw-Hill Companies, New York, p.683

Smith, K.A. (1995). *Cooperative Learning: Effective Teamwork for Engineering Classrooms*, http://fie.engrng.pitt.edu/fie95/2b5/2b54/2b54.htm

Engineering Graphics Educational Outcomes for the Global Engineer

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Abstract

Graphics has always been a requisite form of communication for engineering practice. The history of major engineering accomplishments is replete with examples of graphical communications, from styli etchings on clay tablets to near-recent blueprint drawings. Modern engineering graphics instruction has been significantly influenced by the advancement of computers and other new technologies over the past few decades. During this short span, the discipline has gone from teaching manual drafting and pencil drawings to the use of 3-D computer modeling and simulation software. Because of these new technologies, engineering graphics is much more available and transportable in the increasing global engineering enterprise. This paper reviews the recent developments in engineering graphics education and proposes a set of student learning outcomes in engineering graphics for the global engineer.

Graphics: The Natural Language for Engineering

Graphics has always been the language of engineering and the preferred media for conveyance of design ideas. The first record of what appears to be an engineering drawing is a temple plan from 2130 B.C. The temple plan was found inscribed on the tablet that is part of a statue (Figure 1). The statue includes a stylus and a notched bar that resembles a scale. The headless statue shows Gudea, a builder and governor of the country later known as Babylon. From Egyptian times, dated about 1500 B.C., papyrus remnants have been found of drawings that used a grid of straight lines made by touching the papyrus with a string dipped in ink pigment, thus setting the stage for early "drafting" practices. The first written record discussing drafting and the use of geometry for design representation is given by Vitruvius, a Roman builder from the turn of A.D. In his "Ten Books of Architecture" Vitruvius

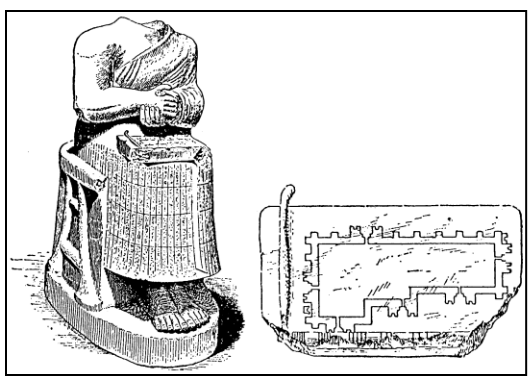

Figure 1. An early form of engineering graphics shows an etching on a clay tablet.

(1914) writes how "an architect must have a knowledge of drawing so he can make sketches of his ideas."

There are interesting records of how great Roman builders used paved city squares as drawing boards. Full size elevation details were chiseled into the stone pavement and used to cut marble blocks that would then fit the erected building with required precision (Figure 2). In about 1500 A.D., the first record of what could be called related multi-view projections appeared in Renaissance Italy. Some of the engineers and inventors of that time were also famous artists. Drawings left by Leonardo da Vinci (Figure 3) were artistic pictorial sketches that resemble axonometric sketching techniques still taught and in use today.

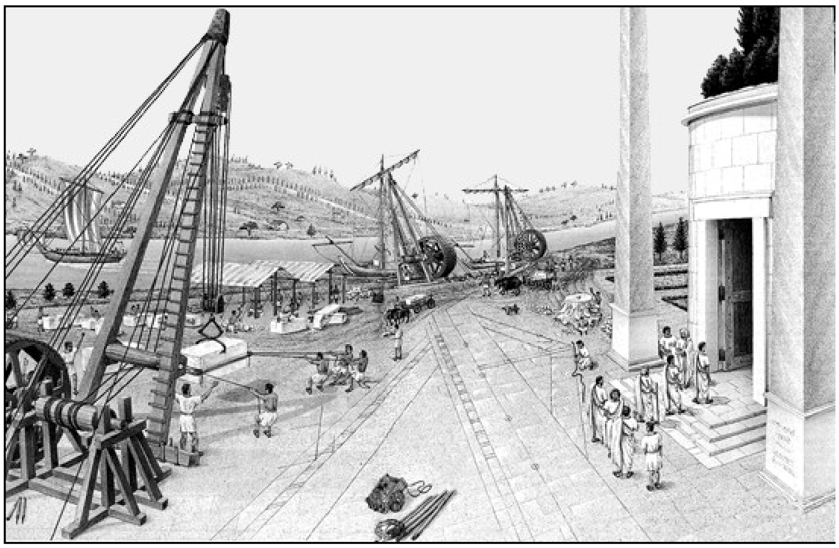

Figure 2. Roman builders engraved details of buildings on pavement.

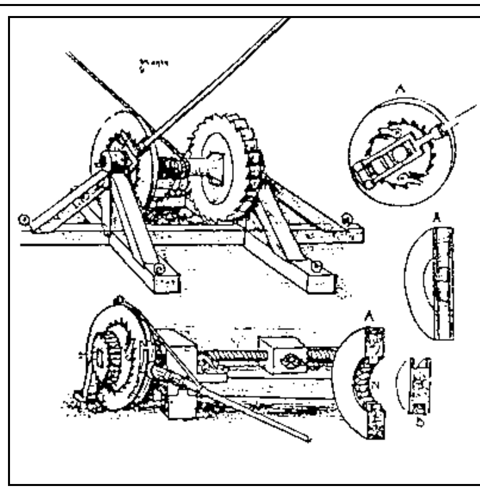

Figure 3. Renaissance sketches by Leonardo da Vinci used techniques still common today.

In 1795, Gaspard Monge published his well-known treatise on descriptive geometry, which provided a scientific foundation to engineering graphics (Booker, 1963). Monge was a mathematician who was assigned to the drafting section of a military school in France. While working on fortification projects, he replaced the computed measurement method with graphical solutions that considerably shortened the time necessary to produce solutions to spatial problems (Figure 4).

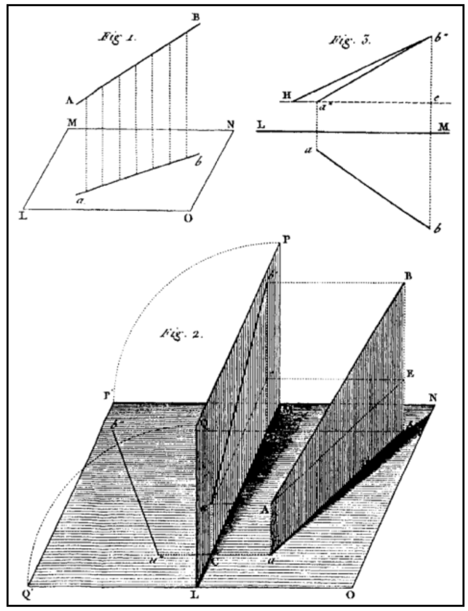

Figure 4. The method of descriptive geometry used graphical projections to solve spatial problems.

During the past century, engineering graphics used different manual tools that made production of orthographic projection drawings easier. Drafting boards, T-squares, and mechanical pencils were common equipment purchased by engineering students. Typical work rooms, with engineers huddled over large drafting boards, were emblematic of the practice of engineering for the better part of the past century. The development of the computer hailed yet a new era in engineering graphical communication technology. The first application of computers to engineering design graphics resulted in Computer-Aided Design and Drafting (CADD) systems that replaced drawing boards with an electronic tool (Figure 5).

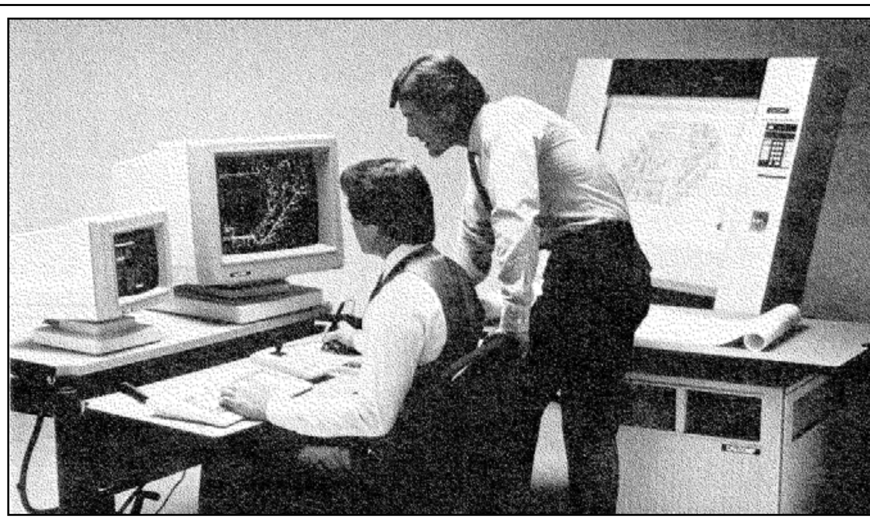

Figure 5. The early use of computers for engineering graphics consisted of electronic drafting systems.

The 3-D Computer Modeling Era in Engineering Graphics Education

Within the past two decades, the teaching of 3-D solid modeling has become the central theme in most engineering graphics programs. This recent paradigm shift to 3-D has been facilitated by the development and low-cost availability of solid modeling software that allows the student to focus on the "bigger-picture" approach to engineering graphical communication. In this concurrent engineering approach (Barr, et al. 1994), the 3-D geometric database serves as the hub for all engineering communication activities (Figure 6). These communications include engineering analysis, simulation, assembly modeling, prototyping, and final drafting and other documentation.

In the concurrent engineering paradigm for graphical communication, the student starts with a sketch of an idea (Figure 7). The sketch idea can then be used to build a solid model of the part. The solid model not only serves as a visualization modality, but it also contains the solid geometry data needed for engineering analysis. Typical of these analyses are finite element meshing, stress and thermal studies, mass properties reports, and clearance-interference checking. After analysis, the same geometric database can be used to generate final communications like engineering drawings, marketing brochures, and even rapid physical prototypes that can be held in one's hand.

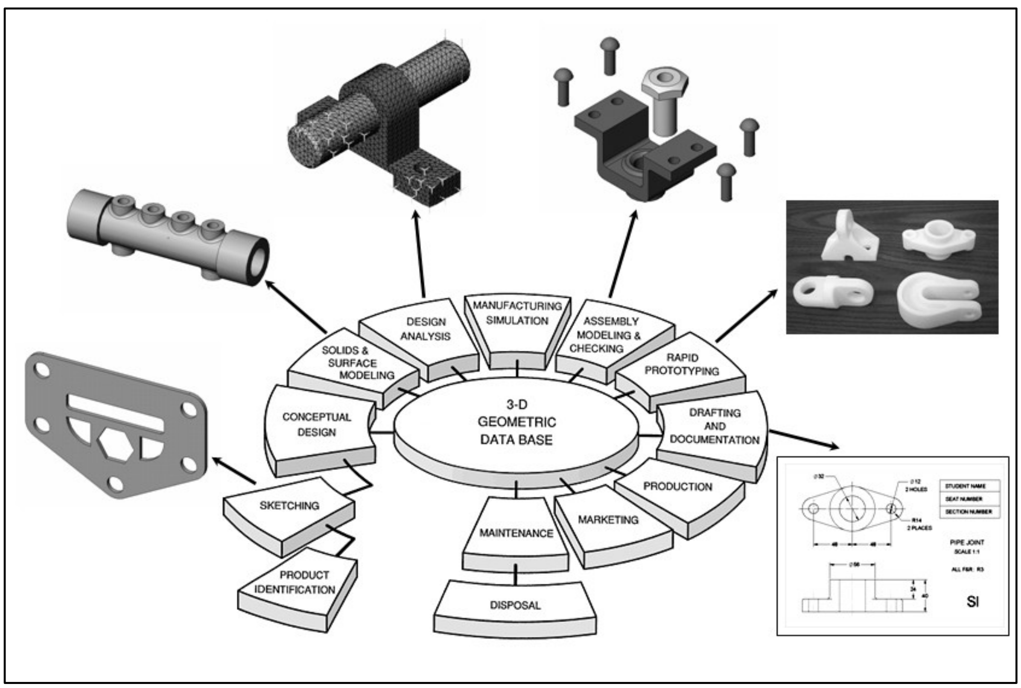

Figure 6. The concurrent engineering design paradigm uses the 3-D geometric model database as the center of all communication activities.

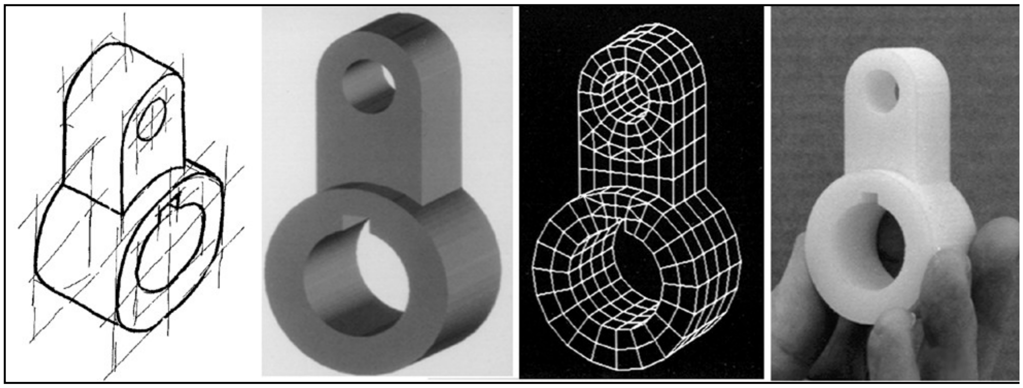

Figure 7. The modern engineering graphics process starts with a sketch idea that is transformed into a solid computer model. The model geometry can be analyzed for certain properties and a 3-D prototype can be printed.

ABET Criterion 3(g)

The new ABET Criteria (ABET, 2011) have profoundly changed the way engineering faculty must review their undergraduate curriculum. This new ABET standard require an outcomes-based approach. Each program is expected to define a set of student outcomes, which are the knowledge, skills, and abilities that must be attained at graduation. Then the engineering programs must continually assess its constituents, including students and alumni, to determine if the outcomes are being achieved. A recommended list of eleven outcomes are presented in ABET Criterion 3 (items a to k). One such criterion 3(g) states that students must possess an "ability to communicate effectively." While the communication modes are not explicitly stated by ABET, many engineering programs interpret this criterion 3(g) to be "ability to communicate effectively in written, oral, and graphical forms." Thus, there is a strong argument that engineering faculty should address the graphical communication abilities of their students, along with all their other outcomes assessment practices.

Developing Student Outcomes for Engineering Graphics Education

In an effort to attain consensus on student outcomes for engineering graphics, a survey was conducted amongst engineering graphics faculty. This survey presented a list of potential engineering graphics outcomes derived from a literature search of related journal papers (Barr, 1999; Meyers, 2000; Branoff, et al. 2002; Smith, 2003; Bertozzi, et al. 2007; Planchard, 2007). This resulted in a list of fourteen major graphics outcomes, and included a sub-list of performance criteria, that demonstrate the achievement of that outcome. In all, over 80 questions were posed to the faculty respondents (N=24), who were asked to rank each outcome or performance criteria using a numerical scale of 1 (Not Important at All) to 5 (Very Important). The survey form is included as an Appendix 1 at the end of this paper.

The following Table 1 below lists the fourteen outcomes and describes some of the graphical activities associated with the outcome. Figures 8 to 13 illustrate some of these engineering graphics outcomes.

Table 1. Fourteen Proposed Educational Outcomes for Engineering Graphics
Outcome 1*:* **Ability to Sketch Engineering Objects in the Freehand Mode**. This outcome includes making sketches in isometric, oblique, perspective, orthographic, and auxiliary view modes. It also includes freehand lettering and freehand dimensioning.
Outcome 2*:* **Ability to Create Geometric Construction with Hand Tools.** This outcome includes using hand tools to draw parallel and perpendicular lines, and to construct circles, arcs, tangencies, and irregular curves.
Outcome 3: Ability to Create 2-D Computer Geometry. This outcome includes setting up grids and units. It also includes creating and editing 2-D computer geometry, and constructing lines, primitives, arcs, and fillets.
Outcome 4: **Ability to Create 3-D Solid Computer Models**. This outcome deals with the ability to extrude and revolve 3-D parts. It includes adding and replicating 3-D design features such as linear and radial arrays.
Outcome 5: **Ability to Visualize 3-D Solid Computer Models.** This is a companion outcome to Outcome 4 and includes setting view direction, panning, and zooming the model, and setting other view controls.
Outcome 6: **Ability to Create 3-D Assemblies of Computer Models.** This outcome deals with mating several parts into a computer assembly model.
Outcome 7: Ability to Analyze 3-D Computer Models. This outcome pertains to analysis of the computer model, including measuring geometry, obtaining mass properties, or creating a mesh to perform a finite element stress study. Included also are simulation studies for heat transfer, fluid flow, and other advanced analysis modes.
Outcome 8: **Ability to Generate Engineering Drawings from Computer Models**. This outcome includes projecting a drawing from a solid model as well as completing the drawing with drafting details.
Outcome 9: Ability to Create Section Views. This outcome deals with section views in 2-D drawings and 3-D computer models..
Outcome 10: **Ability to Create Dimensions.** This outcome includes applying standard vertical, horizontal, radius, diameter, and other dimensions to an engineering drawing.
Outcome 11: **Knowledge of Manufacturing and Rapid Prototyping Methods.** This outcome deals with common shop and manufacturing processes that impact drawings, as well as modern rapid prototyping methods.
Outcome 12: **Ability to Solve Traditional Descriptive Geometry Problems**. This outcome covers the classical projective solutions to spatial problems.
Outcome 13: **Ability to Create Presentation Graphics.** This outcome includes creating data graphs and charts, generating color raster images, and creating animations and slide show presentations.
Outcome 14: **Ability to Perform Design Projects**. This final outcome deals with team work, technical reporting, the design process, and reverse engineering.

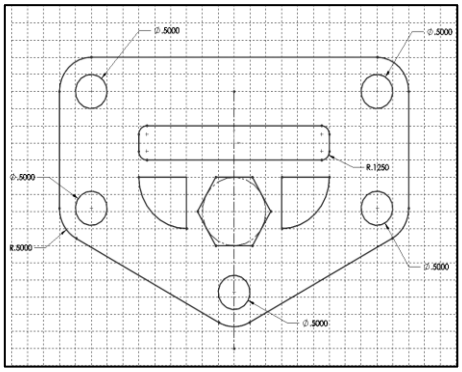

Figure 8. Sketching a 2-D profile

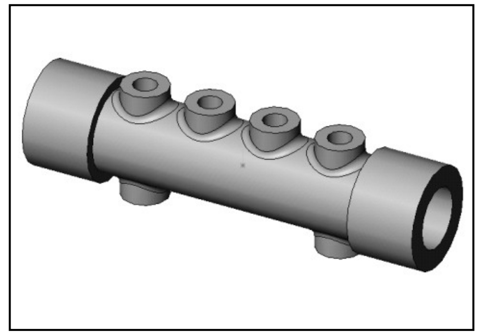

Figure 9. Building a 3-D part and applying design features.

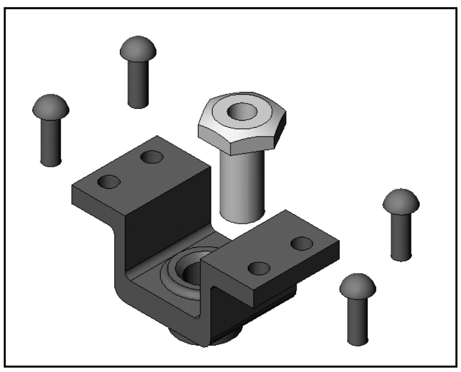

Figure 10. Mating 3-D parts into a computer assembly model.

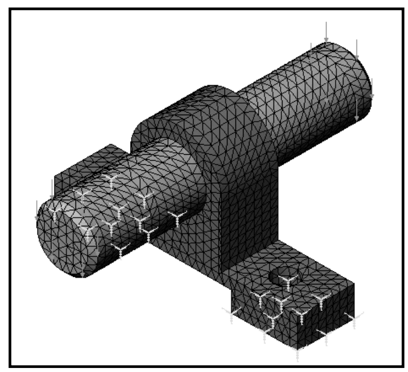

Figure 11. Creating a mesh and performing a finite element study.

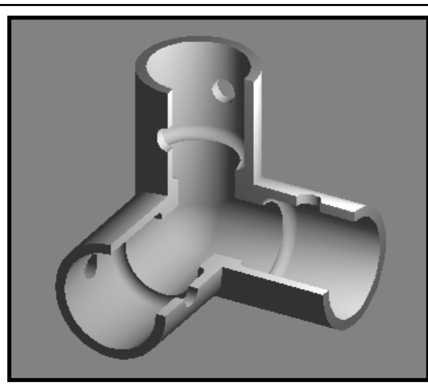

Figure 12. 3-D section view of a part showing internal features.

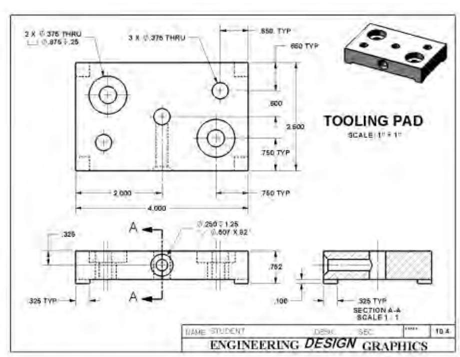

Figure 13. A Final drawing projected directly from the solid model.

Results of Faculty Outcome Survey

The survey results (Barr, et al. 2004) for the proposed fourteen graphics outcomes are shown in Table 2, listed from highest to lowest ranking. The highest ranked outcome was Outcome 4, ability to create 3-D solid computer models. This supports the earlier contention that "3-D solid modeling has become the central theme in most engineering graphics programs." Indeed, four of the top seven ranked outcomes pertain to modern computer tools to generate a graphical image. In addition, several traditional graphics topics (sketching, dimensioning, engineering drawings, and section views) were also ranked high, receiving average rankings above 4.10. On the other hand, the long-standing traditional topics of descriptive geometry and manual geometric construction techniques, were soundly rejected by the respondents. They were the only two topics that received average rankings below 3.00.

Table 2. Faculty Ranking of Fourteen Proposed Engineering Graphics Outcomes
(Listed from Highest to Lowest Ranking)

Proposed Graphics Outcome	Average Rank
4. Ability to Create 3-D Solid Computer Models	4.75
1. Ability to Sketch Engineering Objects in the Freehand Mode	4.67
5. Ability to Visualize 3-D Solid Computer Models	4.46
10. Ability to Create Dimensions	4.38
8. Ability to Generate Engineering Drawings from Computer Models	4.33
6. Ability to Create 3-D Assemblies of Computer Models	4.29
3. Ability to Create 2-D Computer Geometry	4.21
9. Ability to Create Section Views	4.13
14. Ability to Perform Design Projects	3.96
7. Ability to Analyze 3-D Computer Models	3.71
11. Knowledge of Manufacturing and Rapid Prototyping Methods	3.42
13. Ability to Create Presentation Graphics	3.42
12. Ability to Solve Traditional Descriptive Geometry Problems	2.29
2. Ability to Create Geometric Construction with Hand Tools	2.13

In addition to the rankings of the fourteen major graphics outcomes, the survey also polled the performance criteria for each outcome. As an example, the results of the performance criteria rankings for Outcome 1, ability to sketch in the freehand mode, are shown in Table 3. It can be seen that some sketching modes (isometric and orthographic) are deemed highly pertinent, while other sketching modes (oblique and perspective) were rated as less important. Comparable variations in the performance criteria rankings were true for the other thirteen major outcomes.

Table 3. Ranking of Performance Criteria for Outcome 1. *(Listed from Highest to Lowest Ranking)*	
Performance Criteria	**Average Rank**
Demonstrate ability to make orthographic multi-view sketches	4.71
Demonstrate ability to make isometric sketches	4.54
Demonstrate ability to apply dimensions to freehand sketches	4.25
Demonstrate ability to make section view sketches	4.17
Demonstrate ability to make auxiliary view sketches	3.04
Demonstrate ability to do freehand lettering	2.79
Demonstrate ability to make oblique sketches	2.46
Demonstrate ability to make perspective sketches	2.38

Student Graphics Outcomes Survey

An outcomes survey was made specifically for students taking the engineering graphics course at the author's home institution. The survey asked the students to rate their skill/ability in sixteen graphics topics that comprise the extent of learning in the course, using a 5-point rating scale from 1 (no skill/ability) to 5 (very significant skill/ability). The survey was administered twice during the semester, during week three (Pre-) and during week fourteen (Post-). A sample of the survey form is shown in Appendix 2.

Results of the student graphics outcomes survey are shown in Table 4. The table shows the average pre- and post-rankings for all the students (N=151) in the class for the Fall 2011 semester. The same data is presented in a graphical form in Figure 14. It can be seen that there are dramatic gains in all sixteen outcomes, as reported by the students. Specifically, all graphics outcomes in the student survey had a pre- to post- gain well over one full ranking point. The lowest gain was 1.23 for lettering and use of instruments, a skill that many students already possessed, since it also had the highest pre- ranking score. On the other hand, the highest gain was for reverse engineering and design projects, with a pre- to post- ranking gain of 2.36. This is a gratifying resultant, because the graphics faculty places much emphasis in the course on team-based, reverse engineering design projects. It can be noted that several other high gains included orthographic sketching (gain = 2.30), computer assembly modeling (gain = 2.29), and computer applications to design and manufacturing (gain = 2.24). These topics are clearly new to the students and the survey results demonstrate learning was accomplished, based on student-reported data.

Table 4. Student Graphics Outcomes Survey			
Desired Graphics Outcome	**Pre**	**Post**	**Gain**
1. Lettering and Use of Instruments	3.22	4.45	1.23
2. Geometric Constructions	3.05	4.41	1.36
3. Isometric Sketching	2.75	4.52	1.77
4. Oblique Sketching	2.10	4.34	2.24
5. Orthographic Sketching	2.11	4.41	2.30
6. 2-D Computer Sketching	3.11	4.64	1.53
7. 3-D Computer Modeling	2.83	4.52	1.69
8. Computer Assembly Modeling	2.06	4.35	2.29
9. Auxiliary Views	1.95	4.19	2.24
10. Design and Manufacturing Features in Graphics	2.01	4.24	2.22
11. Computer Model Applications to Design and Manufacturing	1.97	4.20	2.24
12. Section Views	2.31	4.18	1.87
13. Dimensioning of Linear and Circular Features	2.75	4.26	1.51
14. Dimensioning Using Symbols and Notes	2.49	4.10	1.62
15. Layout of Engineering Drawings from 3-D Computer Models	2.27	4.31	2.04
16. Reverse Engineering and Design Projects	2.01	4.37	2.36

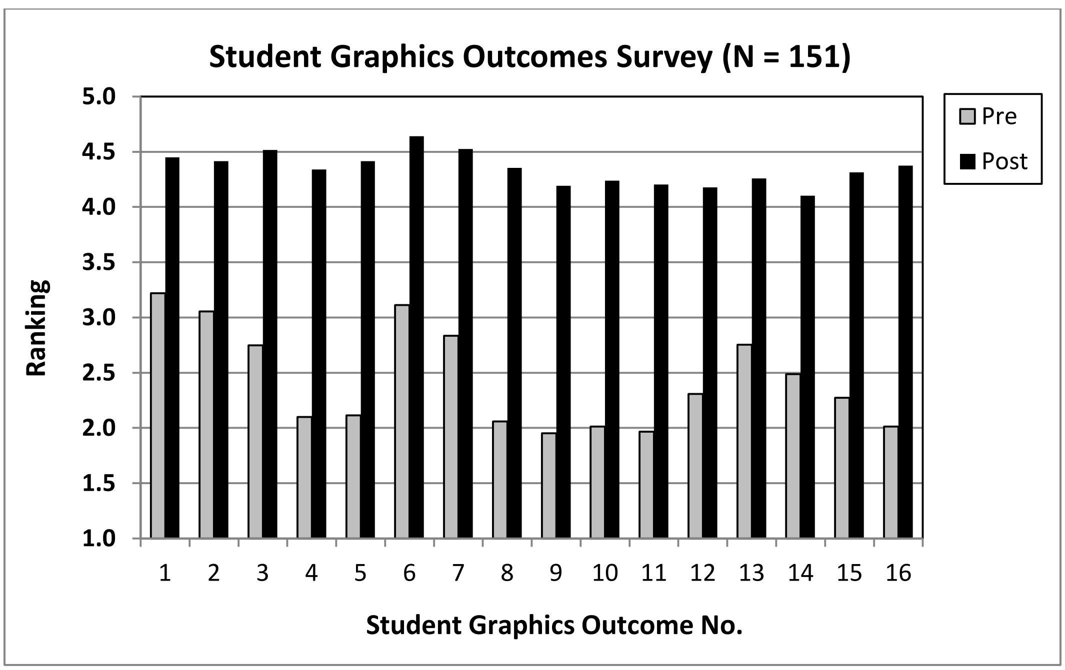

Figure 14. Results of the student graphics outcomes survey comparing pre- and post-rankings. Dramatic gains in all outcomes are demonstrated.

Project-Based Engineering Graphics Education

Many engineering graphics educational programs use some form of a student project, in conjunction with teaching the graphics theory, to inspire the students with hands-on applications. One example that is currently popular is reverse engineering. Reverse engineering is a systematic methodology for analyzing the design of an existing device or system. The project consists of student teams selecting and reverse engineering a mechanical device through a dissection and documentation process. The students first plan their project using graphs and charts, such as a Gantt Chart, a Black Box Diagram, and a Fishbone diagram for the dissection process. During dissection, the students make measurements using calipers and scales, and sketch the parts individually and as an assembly to document the dissection process. The previous sketches and documents are used to generate solid 3-D computer models of all the parts, which can then be assembled together into the whole mechanical device. The solid model data base easily facilitates digital analysis such as Mass Properties reports. Dimensioned engineering drawings are also generated from the solid model data base. The solid model data is also saved as an .STL file and sent to a 3-D printer, where hand-held physical prototypes of the parts are made in less than 24 hours. At the end of the semester, the student teams submit a full design report, including the 3-D printed parts, to the instructor. Examples of these activities are shown in Figure 15.

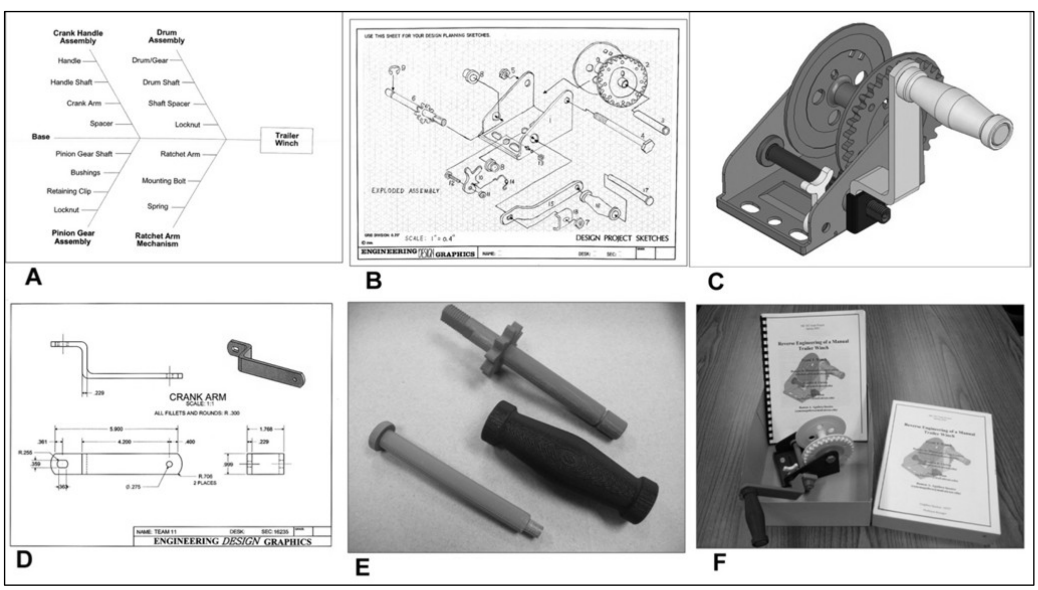

Figure 15. Engineering design graphics activities that are used in the reverse engineering project include: A. fishbone diagram, B. freehand sketching, C. computer assembly modeling, D. engineering drawings, E. physical prototypes, and F. final report.

Simulation as a New Graphics Outcome

Simulation is the newest extension of solid modeling software that can be used in engineering graphics courses. Simulation studies can include, for example, the flow of fluid through a pipe or the transfer of heat along a plate. Simulation uses mathematical formulas and finite difference algorithms to demonstrate the occurrence of physical phenomena in a solid model or assembly of parts. While the academic level of an engineering graphics student may limit the extent of some simulations, there are some simple intuitive studies that can be run. For example, a thermal analysis study is established to observe the transient heat transfer in a slotted plate. First, the material of the solid plate must be defined so that the various thermal properties of the material can be fixed for the study. In this case, cooper is chosen as the plate material. Then, two corner end surfaces of the plate are fixed at a temperature of 500° F, and the opposite two corner end surfaces are initially set to 65° F. To run the study, the plate is first meshed, so that the solver can interpret the heat transfer across the finite elements using the appropriate numerical equations. Since this is a transient analysis, the temperature distribution can be displayed by the thermal plots at different times. For example, Figure 16 shows the transient heat transfer for this study at 10 seconds.

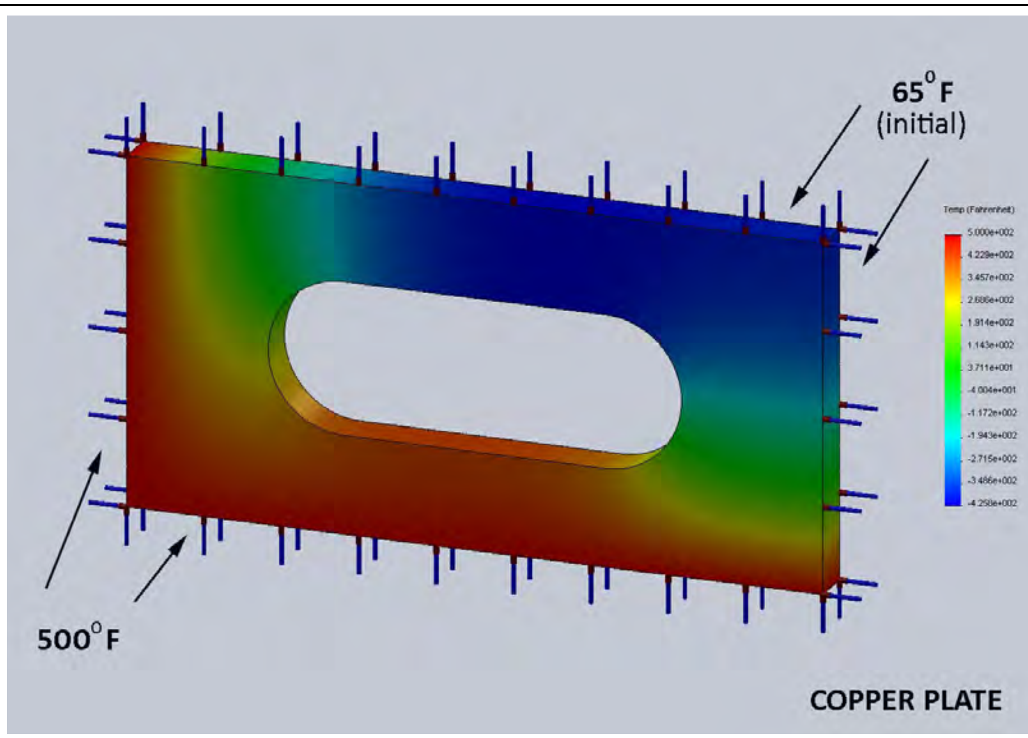

Figure 16. Transient thermal analysis for a slotted copper plate showing heat transfer after 10 seconds.

Conclusions

This paper discusses the formulation of student outcomes for engineering graphics that span the global enterprise. As part of this formulation, graphics outcomes surveys were conducted both in a graphics faculty audience and in a graphics student audience. Results indicate that new computer graphics tools and techniques are now the preferred mode of graphical communication in engineering. Specifically, 3-D computer modeling, assembly modeling, and digital model application to design and manufacturing all received significant notices in the survey results. Results of the faculty survey (Table 2) indicate that long-standing techniques of descriptive geometry and manual geometric construction were no longer desirable outcomes. Results of the student outcomes survey (Table 4) indicate that significant gain in all outcomes can be achieved in a graphics course, albeit in a self-reported manner.

In response to the ABET criterion 3(g) calling for "effective communication" in engineering education, modern engineering graphics should be considered an important form of engineering communication, and should focus on three areas of instruction, as shown in Figure 17. This triad of instruction should include: *a*. engineering graphics fundamentals; *b*. computer graphics modeling; and *c*. computer model applications to digital analysis, manufacturing, and design projects. The author looks forward to further discussions of student graphics outcomes within the global engineering community.

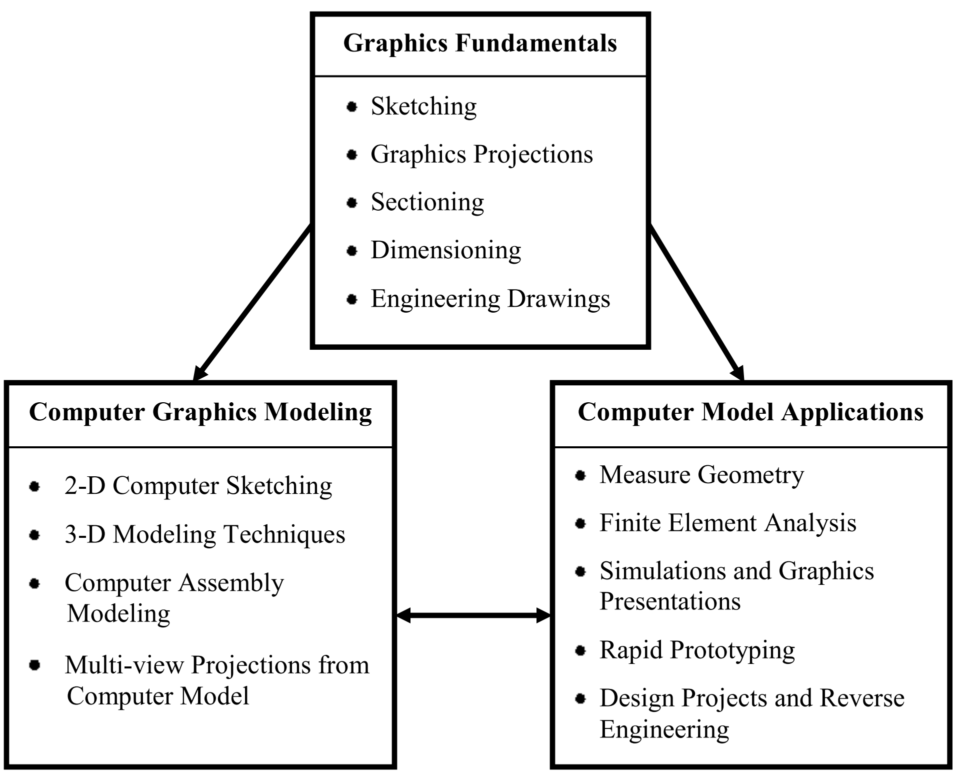

Figure 17. The triad of modern engineering graphics instruction

References

ABET (2011), *Criteria for Accrediting Engineering Programs*, Accreditation Board for Engineering and Technology, Baltimore, Maryland.

Barr, R. E., Juricic, D., and Krueger, T. J. (1994): “The Role of Graphics and Modeling in the Concurrent Engineering Environment,” *Engineering Design Graphics Journal*, 58(3):12-21.

Barr, R. E. (1999): “Planning the EDG Curriculum for the 21st Century: A Proposed Team Effort,” *Engineering Design Graphics Journal*, 63(2):4-12.

Barr, R. E., Krueger, T. J., and Aanstoos, T. A. (2004): “Results of an EDG Student Outcomes Survey,” *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition,* Salt Lake City, Utah.

Bertozzi, N., Hebert, C., Rought, J., and Staniunas, C. (2007): “Implementation of a Thre-Semester Concurrent Engineering Design Sequence for Lower-Division Engineering Students,” *Engineering Design Graphics Journal*, 77(1):1-13.

Booker, P. J., (1963): *A History of Engineering Drawing.* Chatto and Windus, London.

Branoff, T. E., Hartman, N. W., and Wiebe, E. N. (2002): “Constraint-Based Three Dimensional Solid Modeling in an Introductory Engineering Graphics Course: Re-Examining the Curriculum,” *Engineering Design Graphics Journal*, 66(1):5-10.

Meyers, F. D. (2000): “First Year Engineering Graphics Curricula in Major Engineering Colleges,” *Engineering Design Graphics Journal*, 64(2):23-28.

Planchard, M. (2007): 3D CAD: A Plus for STEM Education, *Engineering Design Graphics Journal*, 71(2):1-4.

Smith, S. S. (2003): “A Design-Based Engineering Graphics Course for First-Year Students,” *Engineering Design Graphics Journal,* 67(2):33-42.

Vitruvius (1914): *The Ten Books on Architecture* (Translated by M. H. Morgan), Harvard University Press, Cambridge, Mass.

Appendix 1: Engineering Graphics Outcomes Survey by Faculty

Please circle the number corresponding to the level of importance you would rate for each proposed EDG Student Outcome (bold) and the related Performance Criteria using the following scale:

1	**2**	**3**	**4**	**5**
Not Important at All		*Somewhat Important*		*Very Important*

	STUDENT OUTCOME	RATING (circle one)				
Ability to Sketch Engineering Objects in the Freehand Mode		1	2	3	4	5
	Demonstrate ability to make isometric sketches	1	2	3	4	5
	Demonstrate ability to make oblique sketches	1	2	3	4	5
	Demonstrate ability to make perspective sketches	1	2	3	4	5
	Demonstrate ability to make orthographic multi-view sketches	1	2	3	4	5
	Demonstrate ability to make auxiliary view sketches	1	2	3	4	5
	Demonstrate ability to make section view sketches	1	2	3	4	5
	Demonstrate ability to apply dimensions to freehand sketches	1	2	3	4	5
	Demonstrate ability to do freehand lettering	1	2	3	4	5
Ability to Create Geometric Construction with Hand Tools		1	2	3	4	5
	Demonstrate ability to construct parallel and perpendicular lines	1	2	3	4	5
	Demonstrate ability to construct arcs, circles, and polygons	1	2	3	4	5
	Demonstrate ability to construct tangencies and irregular curves	1	2	3	4	5
Ability to Create 2-D Computer Geometry		1	2	3	4	5
	Demonstrate ability to set up grids, units, and sketch planes	1	2	3	4	5
	Demonstrate ability to create 2-D lines and primitives	1	2	3	4	5
	Demonstrate ability to a use 2-D editing features	1	2	3	4	5
	Demonstrate ability to apply relations and dimensions to 2-D sketch	1	2	3	4	5
Ability to Create 3-D Solid Computer Models		1	2	3	4	5
	Demonstrate ability to extrude or revolve 2-D profiles into 3-D model	1	2	3	4	5
	Demonstrate ability to apply Boolean operations to 3-D primitives	1	2	3	4	5
	Demonstrate ability to add 3-D features to a base computer model	1	2	3	4	5
	Demonstrate ability to edit 3-D features of a computer model	1	2	3	4	5
Ability to Visualize 3-D Solid Computer Models		1	2	3	4	5
	Demonstrate ability to set view direction	1	2	3	4	5
	Demonstrate ability to select axonometric or orthographic views	1	2	3	4	5
	Demonstrate ability to pan, rotate, and zoom computer model	1	2	3	4	5
	Demonstrate ability to set the transparency of model faces and edges	1	2	3	4	5
	Demonstrate ability to use stereo or virtual reality to view computer models	1	2	3	4	5
Ability to Create 3-D Assemblies of Computer Models		1	2	3	4	5
	Demonstrate ability to move and rotate individual parts in an assembly	1	2	3	4	5
	Demonstrate ability to mate individual parts in an assembly	1	2	3	4	5
	Demonstrate ability to color parts in an assembly	1	2	3	4	5
	Demonstrate ability to explode an assembly of parts	1	2	3	4	5
Ability to Analyze 3-D Computer Models		1	2	3	4	5
	Demonstrate ability to measure geometry of a computer model	1	2	3	4	5
	Demonstrate ability to analyze mass properties of a computer model	1	2	3	4	5
	Demonstrate ability to perform finite element analysis (FEA)	1	2	3	4	5
	Demonstrate ability to use spreadsheets, design tables and other solvers	1	2	3	4	5
*	Demonstrate ability to use simulation software on computer models	1	2	3	4	5

Ability to Generate Engineering Drawings from Computer Models	1	2	3	4	5
Demonstrate ability to set up a drawing sheet in computer space	1	2	3	4	5
Demonstrate ability to project orthographic/auxiliary views into a drawing	1	2	3	4	5
Demonstrate ability to set visible and hidden lines on the drawing	1	2	3	4	5
Demonstrate ability to set proper centerlines on the drawing	1	2	3	4	5
Demonstrate ability to insert a title block and annotations on the drawing	1	2	3	4	5
Ability to Create Section Views	1	2	3	4	5
Demonstrate ability to create a section view of a 3-D computer model	1	2	3	4	5
Demonstrate ability to generate a 2-D section view from computer model	1	2	3	4	5
Demonstrate knowledge of various types of section views	1	2	3	4	5
Demonstrate knowledge of cross-hatching practices in section views	1	2	3	4	5
Ability to Create Dimensions	1	2	3	4	5
Demonstrate ability to apply vertical and horizontal dimensions	1	2	3	4	5
Demonstrate ability to apply diameter and radius dimensions	1	2	3	4	5
Demonstrate ability to apply standard dimension notes	1	2	3	4	5
Demonstrate ability to apply tolerances to dimensions	1	2	3	4	5
Demonstrate ability to apply thread notes	1	2	3	4	5
Knowledge of Manufacturing and Rapid Prototyping Methods	1	2	3	4	5
Demonstrate knowledge of common design features (fillets, rounds, etc.)	1	2	3	4	5
Demonstrate knowledge of machine shop processes (lathe, mill, drill, etc.)	1	2	3	4	5
Demonstrate knowledge of welding and fastening	1	2	3	4	5
Demonstrate knowledge of material selection practices	1	2	3	4	5
Demonstrate knowledge of rapid prototyping	1	2	3	4	5
Demonstrate knowledge of concurrent engineering and product life-cycle	1	2	3	4	5
Ability to Solve Traditional Descriptive Geometry Problems	1	2	3	4	5
Demonstrate ability to locate points, lines, and planes in space	1	2	3	4	5
Demonstrate ability to solve line and plane relationship problems	1	2	3	4	5
Demonstrate ability to solve spatial curve problems	1	2	3	4	5
Demonstrate ability to solve dihedral angle problems	1	2	3	4	5
Demonstrate ability to solve revolution problems	1	2	3	4	5
Demonstrate ability to solve intersection and development problems	1	2	3	4	5
Demonstrate ability to solve topographic problems	1	2	3	4	5
Demonstrate ability to solve graphical vector geometry problems	1	2	3	4	5
Ability to Create Presentation Graphics	1	2	3	4	5
Demonstrate ability to make rendered color hardcopies of computer models	1	2	3	4	5
Demonstrate ability to make kinematics animation files of computer models	1	2	3	4	5
Demonstrate ability to make data graphs and charts	1	2	3	4	5
Demonstrate ability to make electronic computer slide shows	1	2	3	4	5
Demonstrate ability to make graphics presentations on the WWW	1	2	3	4	5
Ability to Perform Design Projects	1	2	3	4	5
Demonstrate knowledge of the design process	1	2	3	4	5
Demonstrate ability to work in teams	1	2	3	4	5
Demonstrate knowledge of reverse engineering	1	2	3	4	5
Demonstrate ability to write a technical report	1	2	3	4	5
Demonstrate ability to make an oral technical presentation	1	2	3	4	5

Appendix 2: Student Evaluation of Outcomes

How would you describe your skills and abilities supporting each outcome below at this stage of the course? (*Circle the appropriate numerical response*.)

Desired Graphics Student Outcomes	Graphics Outcomes Ranking				
	No skill/ability	A little skill/ability	Some skill/ability	Significant skill/ability	Very Significant skill/ability
1. Lettering and Use of Instruments	**1**	**2**	**3**	**4**	**5**
2. Geometric Constructions	**1**	**2**	**3**	**4**	**5**
3. Isometric Sketching	**1**	**2**	**3**	**4**	**5**
4. Oblique Sketching	**1**	**2**	**3**	**4**	**5**
5. Orthographic Sketching	**1**	**2**	**3**	**4**	**5**
6. 2-D Computer Sketching	**1**	**2**	**3**	**4**	**5**
7. 3-D Computer Modeling	**1**	**2**	**3**	**4**	**5**
8. Computer Assembly Modeling	**1**	**2**	**3**	**4**	**5**
9. Auxiliary Views	**1**	**2**	**3**	**4**	**5**
10. Design and Manufacturing Features in Graphics	**1**	**2**	**3**	**4**	**5**
11. Computer Model Applications to Design and Manufacturing	**1**	**2**	**3**	**4**	**5**
12. Section Views	**1**	**2**	**3**	**4**	**5**
13. Dimensioning of Linear and Circular Features	**1**	**2**	**3**	**4**	**5**
14. Dimensioning Using Symbols and Notes	**1**	**2**	**3**	**4**	**5**
15. Layout of Engineering Drawings from 3-D Computer Models	**1**	**2**	**3**	**4**	**5**
16. Reverse Engineering and Design Projects	**1**	**2**	**3**	**4**	**5**

PRE / POST

A Delphi Study as a First Step in Developing a Concept Inventory for Engineering Graphics

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Abstract

Unlike many other subjects in engineering such as statics, dynamics, or strength of materials, engineering graphics instruction has changed significantly over the past century. The primary reason for this change is the development of new graphical tools and methods at an increasingly rapid pace. In light of this, it is important that graphics educators keep sight of the fundamentals in graphics education and not rush to change for the sake of new tools. Unfortunately, there is little agreement about what constitutes the fundamentals in graphics education. Further, there appears to be a significant international disconnect among graphics educators regarding what should be included in graphics instruction. In other science and engineering fields, such as physics, mathematics, statistics, and engineering science, concept inventories have been developed in recent years to define the fundamental concepts in those disciplines. The concept inventories provide educators with a standardized instrument that they can use to help design their courses and to determine if their students understand the fundamentals. The authors of this paper propose to conduct a Delphi study to define the fundamentals in graphics education. A Delphi study is viewed by many as the first step in the development of a concept inventory. This paper outlines the proposed study and describes the necessary next steps in the process.

History

Engineering graphics began in the mid-eighteenth century when Gaspard Mongé developed a method of graphically describing three dimensional solids and spatial relationships by means of interrelated projections on a two dimensional drawing surface. Considered the inventor of descriptive geometry, Mongé, used his calculations to aid the accuracy of artillery fire. Descriptive geometry techniques required painstaking attention to detail through the use of drafting tools and is still a fundamental topic in many European engineering programs.

Engineering graphics in the United States was based on a more pragmatic approach and the direct method of descriptive geometry was developed at West Point in the late nineteenth century. In the beginning of the twentieth century, engineering graphics education in the United States had a strong mechanical influence because mechanical engineering was the dominant discipline in teaching and developing the course topics. Most engineering schools required at least one engineering graphics course, many institutions required more than one, and many stand-alone engineering graphics departments existed. The early influence of mechanical engineering can still be seen in most engineering graphic textbooks today. (Pleck et al.) As shown in Figure 1, the history of engineering graphics has spanned more than a century and changed significantly over the decades.

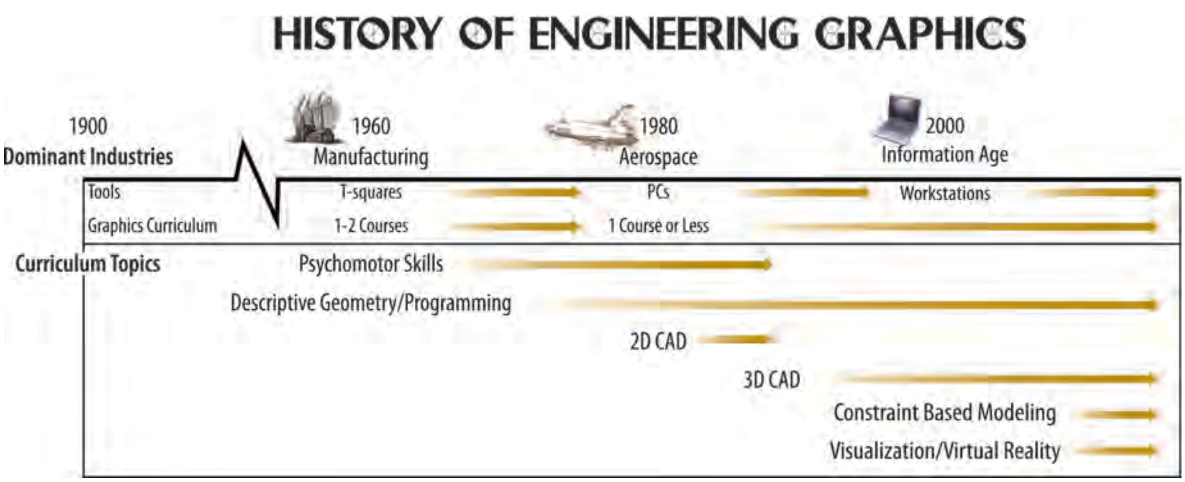


Figure 1. History of Engineering Graphics

Throughout its history, engineering graphics has embraced the "tool of the day" migrating from hand-drafting tools such as T-squares and dividers to 2-D CAD software and finally to 3-D CAD fully integrated design systems. Graphics educators have discussed the benefits of one CAD package versus another; they have debated the need for inclusion of topics such as those found in traditional descriptive geometry; they have focused on local industry needs in designing their graphics courses; however, they have rarely, if ever, discussed the foundational concepts that should be included in a graphics course at any level. The Delphi study proposed here seeks to define these foundational concepts so that educators can design their courses to meet the needs of today's students who will likely experience many changes in tools and graphics techniques over their careers.

Concept Inventories

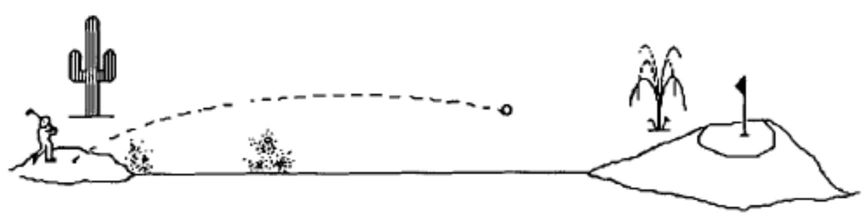
A concept inventory is an instrument that helps faculty identify the concepts that their students do not understand and decide which misconceptions are the most prevalent. In addition, concept inventories can help define important fundamental topics for instruction and learning. The first concept inventory was the Force Concept Inventory developed and implemented by Hestenes

(1992) in the area of physics education. It was developed as a test to identify students' misconceptions about Newtonian Force. Since the successful implementation of the Force Concept Inventory, there has been a strong interest in developing concept inventories for other STEM fields. The NSF-funded Foundation Coalition, headed by D. D. Evans (2003) at Arizona State, began working on developing concept inventories in the engineering disciplines in 2000. In the intervening years, a variety of concept inventories have been developed, including: materials, statics, heat transfer, chemistry, computer engineering, dynamics, and electronics.

The coalition stated in 2003 that "for the most part teaching of engineering subjects continues to be patterned after how instructors were taught when they were students of the subject rather then being informed by research of learning" (Evans et al.). They contended that reform in science, technology, engineering and mathematics (STEM) education is hampered partially due to the lack of good assessment instruments. Once implemented, the Force Concept Inventory assessment designed by Hestenes et al. stimulated a variety of reforms in physics education. "Such assessments can play an important part in relating teaching techniques to student learning." (Hestenes) It is hoped that a concept inventory for graphics education can spur a similar movement of reform.

Figure 2 shows an example of an item found on the Force Concept Inventory. (Force Concept Inventory)

A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the image below. Which following forces is(are) acting on the golf ball during its entire flight? 1. the force of gravity 2. the force of the "hit" 3. the force of air resistance



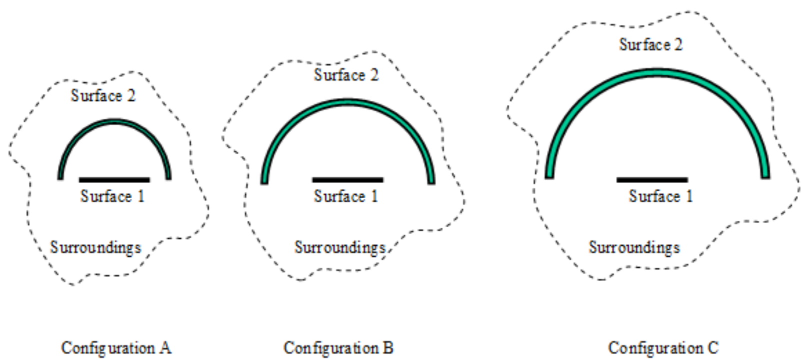
a. 1 only
b. 1 and 2
c. 1, 2 and 3
d. 1 and 3
e. 2 and 3

Figure 2. Force Concept Inventory Item

Figure 3 shows an example of an item from the Heat Transfer Concept Inventory. (Heat Transfer Concept Inventory)

For the three configurations shown below, which is the correct statement about the fraction of the radiation emitted by surface 1 that is incident on surface 2. Surface 1 is the same size in each configuration.

The **fraction** of the radiation emitted by surface 1 that is incident on surface 2 is:



1. greatest for configuration A
2. greatest for configuration B
3. greatest for configuration
4. the same for all configurations

Figure 3. Heat Transfer Concept Inventory Item

The Sorby Test

In 1998, Sorby (along with Mike Young), developed a test as a placement exam for introductory engineering graphics. The test was aimed at first-year engineering students who had taken drafting courses in high school. The items on the test closely mirrored content from the engineering graphics courses found at Michigan Tech at that time. A passing grade on the test enabled students to “place out” of first-year graphics courses at Michigan Tech, although very few of them were able to do so, likely due to a mismatch between the content of high school drafting courses and engineering graphics at the university level. The test consists of 50 items. Some of the items assess a person’s basic level of visualization ability and others assess their understanding of engineering drawing conventions. The test showed good reliability (KR20~0.8); however, it was never validated on a national basis and it included many items that would not be considered suitable for a true concept inventory. Despite this, the test has been used for assessment purposes in engineering graphics courses at Michigan Tech, Rensselaer Polytechnic Institute, and The Ohio

State University since its development. In pre-/post-testing at these sites, it was typically found that students showed statistically significant gains over the course of a term while enrolled in engineering graphics.

Communication Graphics Concept Inventory

Our ultimate goal is to develop an instrument which measures students' conceptual knowledge of graphic communication. According to Allen (2006), the ultimate goal is to develop an instrument which is recognized on a national level as a useful tool for monitoring student learning or on an individual or classroom basis to comparing scores across universities.

Concept inventories are excellent instruments with which to validate the effectiveness of new teaching methodologies and curricular innovations. They can be used to assess student learning and to validate the effectiveness of new methodologies. In many established disciplines, professors teach in the manner in which they learned the subject and while the focus of graphics communication has changed over the years, it is entirely possible that graphics is being instructed in the same way it was taught many years ago. A concept inventory is also a useful tool in helping to define a "discipline." The concepts tested on a concept inventory are typically thought of as fundamental to the discipline itself—if a particular topic is not found on a concept inventory, this often implies that it is of less importance in the grand scheme of things. Being able to focus on the important, fundamental concepts is important in an era of ever-tightening curricula.

Need for a Concept Inventory in Graphics Education

Engineering graphics is one of the highest enrollment courses in all of the STEM fields. Graphics is typically still a requirement for most engineering disciplines, particularly for mechanical and civil engineering. Common first-year engineering programs such as those at Virginia Tech, Texas A&M, Purdue, Ohio State and others contain a strong graphics component. In addition, graphics is taught in pre-engineering and in engineering technology programs at community colleges as well as in high schools. High school graphics is often taught aimed primarily at students who intend to become technicians and is typically taught in a traditional manner, with hand-drafting predominating. No consensus regarding optimal content for graphics courses exists, resulting in a large degree of variation among courses across the country. There is also a large disconnect between graphics in the high school, in the community college, and in the university system. The lack of uniformity in graphics courses is likely due to a lack of an acceptable instrument for assessing fundamental learning in graphics courses. A concept inventory for engineering graphics would assist educators at all levels in two areas: course design and course assessment.

A concept inventory for engineering graphics would identify "core" graphics topics so that educators could focus on these in their course design. A concept inventory would lead to a better connection between graphics courses at all levels, ensuring that high school and community college courses better map to the expectations of university-level graphics courses. A concept inventory would also enable faculty to assess student understanding of fundamental concepts in graphics to evaluate the effectiveness of the courses they teach and to make adjustments as necessary.

Delphi Technique

A Delphi study is a consensus-building forecasting technique that has been used by organizations, agencies, and corporations for making predictions, identifying priorities, and setting agendas (Sadowski). Although this technique was developed in the "business world," a number of educational leaders including Clark & Scales (1999); Paige, Duggar, & Wolansky (1996); Volk (1993); Zargari, Campbell, & Savage (1995); and Sorby et al. (2005) have suggested its use in the design of curricula and programs. In this context, a Delphi study typically consists of four rounds, conducted with a panel of experts, to reach consensus on defining the important elements of a curriculum or the important concepts to be included in a concept inventory. A Delphi study also lends itself to reaching consensus without a need for face-to-face meetings among panel members, making the study relatively easy to implement through mail or online surveys, especially for a panel with broad geographic representation among its members. Over the next year or so, we will employ the Delphi technique in the identification of concepts for the concept inventory for graphic communications.

Conclusion

Engineering graphics is one of the most widely taught subjects in engineering with courses at universities, community colleges, and high schools. Graphics is typically part of the engineering and engineering technology programs as well as related programs such as construction management and many vocational fields. Inclusion of graphics topics in the curriculum has been greatly reduced over the years as engineering programs have struggled to accommodate deeper and deeper cuts in credits to graduation. Tools used in graphics education are constantly and rapidly changing. It is likely that between the time when a student matriculates into a program and the time when s/he graduates that the "tool of choice" will have changed. For this reason, it is necessary to have our graphics courses focus on the fundamentals, i.e., to make our courses "tool resistant." Further, as graphics content is whittled away, we need to make sure that we retain fundamental concepts in order to prepare our students for careers in the coming years. In order for this to happen, graphics educators must have a clear idea of what the fundamentals are and how to assess their teaching with respect to these fundamentals. To this end, a concept inventory fills a gap in graphics education and a Delphi study is the logical first step in the development of this important assessment tool.

References

Allen, K., (2006). *The Statistics concept inventory: Development and analysis of a cognitive assessment instrument in statistics*, Unpublished dissertation, University of Oklahoma.

Clark, A. C., & Scales, A. Y., (1999). Quality Characteristics of a Graduate Teacher Education Program in Graphic Communications: Preliminary Results from a Delphi Research Study, *Proceedings of the 54th Annual Engineering Design Graphics Midyear Meeting*, Biloxi, MS, pp. 45-58.

Evans, D. L., Gray, G.L., Krause, S., Martin, J., Midkiff, C., Notaros, B. M., Pavelich, M., Rancour, D., and Reed-Rhodes, T., (2003). Progress on concept inventory tools. *In 33rd ASEE/IEEE Frontiers in Education Conference Proceedings*. Boulder, CO pp. T4G1 – T4G8.

Force Concept Inventory, (2011). https://dev.cihub.org/resources/6.

Heat Transfer Concept Inventory, (2011). https://dev.cihub.org/resources/10.

Hestenes, D., Wells, M., & Swackhamer, G., (1992). Force Concept Inventory. *The Physics Teacher*, Vol. 30, 141-158.

Paige, W. D., Dugger, J. C., & Wolansky, W. D., (1996). Essential components of doctoral programs in industrial technology education, *Journal of Technological Studies*, Vol. 22/2, pp. 15-20.

Pleck, M. H., McGrath, M. B., Bertoline, G. R., Bowers, D. H., & Sadowski, M. A., (1990). Factors affecting the engineering design graphics curriculum: past, present and future. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum*, pp. 43-51.

Sadowski, Mary A., (1985). Graphics competencies as determined by the Delphi method. *Engineering Design Graphics Journal*, Vol. 49, (1) pp.10-14.

Sorby, S. A., Bohmann, L. J., Drummer,T. D., Frendewey, J. O., Mattila, K. G., and Sutherland, J. W., (2005). Development of a Curriculum for Service Systems Engineering Using a Delphi Technique, *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition*.

Volk, K. S., (1993). Curriculum development uses the Delphi technique, *The Technology Teacher*, Vol. 52/4, pp. 35-36.

Zargari, A., Campbell, M., & Savage, E., (1995). Determination of curriculum content and requirements for a Doctor of Philosophy Degree Program in industrial technology, *Journal of Industrial Teacher Education*, Vol. 32/4, pp. 57-73.

Implementing Reverse Engineering Methodology into First Year Engineering Curricula from a Student Perspective

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Abstract

This paper discusses a study that involved implementing Reverse Engineering (RE) methodology into an introductory engineering graphics course. This study took place at the West Lafayette campus of Purdue University in the fall semester of 2011. The course was selected because of its size and the CAD knowledge that the students obtained throughout the duration of the course. With an enrollment of approximately 400 students this course allowed for the utilization of RE methodology at a large scale and 3D scanning technology on a small scale. By the time in the semester that the study was conducted students had developed 3D CAD knowledge that is needed for RE processes.

The authors will advocate for the implementation of RE methodology and 3D scanning. In addition they will describe the positive and negative experiences of incorporating RE into a first year engineering course. Through the use of qualitative research methodology they will evaluate its acceptance and provide an assessment of its performance in the course by the students involved.

The objective of this study was to determine what factors, from a students' perspective, need to be considered when incorporating RE methodology into engineering curricula. Cost, time, and liability were just a few factors students felt were necessary considerations with the implementation of RE.

Introduction

The concept of incorporating RE methodology into engineering curricula has taken place in universities such as the University of Texas, Massachusetts Institute of Technology, and the United States Air Force Academy as part of teaching engineering design (Wood, Jensen, Bezdek, & Otto, 2001). Purdue University is one university that does not currently offer courses with RE methodology beyond simple projects that consist of measuring an existing part or product. The objective of this study was to incorporate RE methods into an existing engineering graphics course at both a large and small scale.

The course chosen for this study was the Introduction to Graphics for Manufacturing (CGT 163) course at the West Lafayette campus of Purdue University. This course was ideal due to enrollment size and student knowledge of 3D CAD modeling. Over the duration of the semester students were introduced to RE methods, an RE project, and 3D scanning technology. By introducing students to different methods and technology it may be possible to motivate and stimulate students' minds and at the same time draw out their creativity and excitement (Hess, 2000).

Previous studies have evaluated student based on monitoring in class activities, student surveys, and course evaluations (Hess, 2000; Sirinterlikci & Mativo, 2010; Orta, Medoza, Elizalde, & Guerra, 2006; Wood et al., 2001). The idea of this study is to gather students' sentiments regarding the incorporation of RE methodology into their engineering curricula on a deeper level. This paper will examine how students perceive RE implementation through student surveys, 3D scanning exercises, and one-on-one interviews.

Scope

What factors need to be considered when incorporating reverse engineering methodology into engineering curricula? That is the question the study sought to answer from a student perspective. As stated by Tang, Zhu, and Xu, (2010) reverse engineering is the process of analyzing a product or technology to determine how it operates and how it was designed. To determine what first year engineering students think of RE in their curriculum it was necessary to conduct this study in a course that consisted of engineering students at the freshman and sophomore level.

To introduce students to RE processes and 3D scanning it was important to keep in mind that it was improbable that every student in the course would be presented with the opportunity to use the single 3D scanning machine that was available. At a large scale, to reach the entire student enrollment, RE methods, examples, and assignments were introduced all enrolled students. On a small scale a select number of students were given the opportunity to complete a hands-on learning experience based on 3D scanning technology.

The professor for the course educated students on different methods of RE, different tools that are used, and provided examples of different projects that were completed using RE practices. Surveys were given regarding the information introduced in course lectures. Select students were chosen to participate in a hands-on portion of the study involving 3D scanning technology and software using scores from the Purdue Spatial Visualization Test of Rotations (PSVT-R). This study analyzed student interest and knowledge to determine what factors needed to be considered before implementation of reverse engineering into engineering courses could successfully occur.

Methodology

This study consisted of two parts to gain a student perspective on reverse engineering implementation. The first portion included the entire enrollment of the course. For this portion of the study students were given three lectures related to RE methodology. Once the lectures were complete students were given an optional survey via Qualtrics. The second portion of the study allowed some students to use a 3D scanner to get a hands-on experience with RE equipment. The information obtained from these two parts gave insight as to what factors students feel need to be considered with the implementation of RE into first year engineering curricula.

RE Introduction and Surveys

As stated before, students were given an optional survey following the completion of three lectures pertaining to RE methodology and technology. All students were given the lectures during their normal lecture period and asked to take down the information contained within the presentations. This gave students the opportunity to me more familiar with RE methods and allowed them to connect the theory with hands-on applications.

Section one of the lectures pertained to RE methodology. The lecture gave students background on the variety of RE methods that are used such as using pictures, orthographic drawings, metrology equipment, traditional measuring tools, and 3D scanning. It covered what each method was, gave some examples of how it is done and the finished product, and presented benefits and drawbacks to each method. The lecture concluded with reasons why RE is used, why it is important, and project examples.

The second section of the lectures referred to 3D scanning technology as a method of RE. Students were introduced to the 3D scanning machine available at Purdue University through the Engineering Education (ENE) department. The lecture guided students through the scanning process from part preparation, to scanner calibration, scanner configuration, the scanning process, cleaning up the scan once it is complete, and saving and exporting the collected data.

The final lecture of the series was an opportunity for students to complete a hands-on activity during the lecture with the 3D scanner. Teaching assistants set up the scanner and calibrated the scanner to show how it was done. Students were then given the opportunity to complete the acquisition of measurements had they wished to use the machine. Once a few students had completed calibration measurements they were given the chance to scan a small part from a manual powered scooter.

Once the lecture series was complete an email was sent out to all students inviting them to participate in an online survey. The survey included questions about their major, their interest in RE, whether they would like this in their curricula, and other questions relating to the lectures and their thoughts on incorporating RE into their curricula.

Hands-on Learning Experience for Select Students

Upon completion of the lectures and surveys, select students were chosen to participate in a hands-on learning experience using a 3D scanner. At the beginning of the semester, students were given the Purdue Spatial Visualization Test of Rotations (PSVT-R) to access their level of spatial ability.

Being a graphics intensive course requiring spatial ability and visualization, it was determined that averaging the PSVT-R scores with the students' course grades would allow the researcher to identify the highest and lowest spatial ability students among the entire class. Table 1 is sorted according to PSVT-R score (max score = 36) and displays the students' course grades and their spatial ability classification. The student number is merely a random number assigned to each student for classification purposes. The highest 10 scoring students and the lowest 10 scoring students were presented with a consent form that they had to complete to have the opportunity to use the 3D scanning technology. This was done to ensure that five students from each category would be available to participate. If a student did not wish to participate in the study they were bypassed and the next student in line was given the opportunity. Students, from the 20 chosen, submitted consent forms to complete the study but not all 20 provided consent. Among those that did provide consent the highest and lowest five were chosen to bring the number down to the 10 students that participated.

Table 1

Participant Sample

Student	PSVT Score	Course Grade	Spatial Ability Classification
0101	6	97	Low
0323	7	66.1	Low
0423	10	62	Low
1020	10	66	Low
0421	12	61.5	Low
0417	36	93	High
0124	36	97	High
1021	36	97	High
1521	36	97	High
1524	36	98	High

Prior to participating in the study each student was provided with a tutorial on how to set-up and operate a ZScanner 800 3D scanner and asked to read through it. The tutorial was created by the researcher as part of the study for use by university students. It walked students through the process of setting up the hardware, how to calibrate the scanner, how to configure the scanner, customizing scanner settings, the most efficient way to complete a scan, eliminating unwanted data and data clean-up, and how to save and export a scanning project.

Upon arriving for the study students were asked if they had read the tutorial along with some general background questions regarding their education and interests. After being introduced to the scanner and how it operates students were asked to calibrate the scanner. Students' calibration times were recorded using a stopwatch for empirical data.

After completing the calibration process students were required to set the resolution of the scanner and asked to choose which part they wanted to create a scan from. Part one was a bracket support that holds the footrest of a manual powered scooter. The second part was a pipe support that holds the handle bar rod of the manual powered scooter. The bracket support and pipe support are shown in figures one and two respectively.

Figure 1. Bracket support

Figure 2. Pipe support

Once students set the resolution they were required to scan the part of their choosing by following the scanning portion of the tutorial. Scanning the part required the use of ZScan software that is compatible with the 3D scanner. Their progress was periodically monitored to determine when the scan data was sufficient for model creation. The screen capture displayed in Figure 3 represents the 3D facet scan data retrieved from the bracket support part. Randomly chosen from the students' results, it gives the detailed data that was collected during the students study.

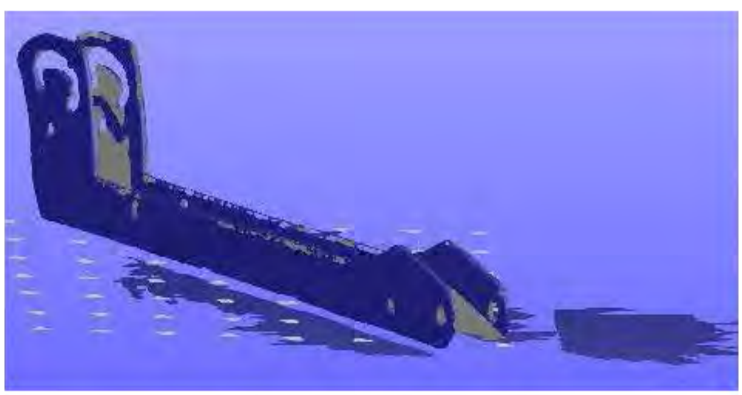

Figure 3. 3D facet data of the bracket support

The dark blue exemplifies the facet data that was captured from the part's surface. The gray represents the reverse side of the captured data having no value to the scan. The white dots stand for the positioning target board that is required for the scanning process. Excess data may sometimes be collected during the process which can be seen in isolated patches separate from the part itself. Figure 4 displays the 3D facet data of the pipe support as scanned by a participating student.

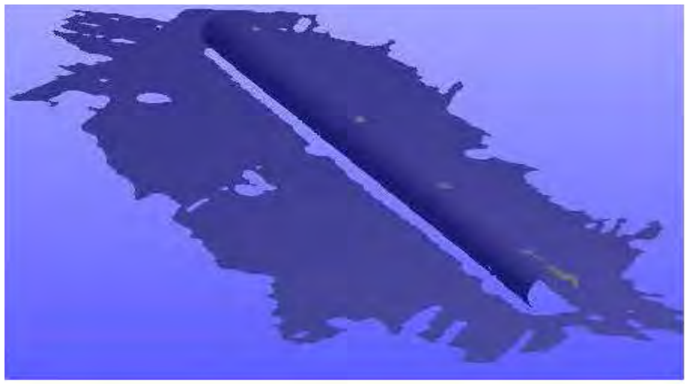

Figure 4. 3D facet data of the pipe support

After obtaining the 3D facet data students were shown how to save their session and export it as a STL file for use with RapidForm software. Students were then shown how to import their STL file into RapidForm and create region groups across the facet data. They were then shown how to create a model using the 3D facet data.

To conclude the session, each student underwent an interview with the researcher. Interview questions pertained to the 3D scanning tutorial, the calibration process, the scanning process, the course they were enrolled in during this study, and the study they completed with the 3D scanner. Students were asked to return for a secondary interview, the waiting period between first and second interviews varied between one day and a week. The interview contained similar questions as the first interview. The waiting period gave students the opportunity to think about the process they had completed with the expectation that during the second interview they would provide additional information they may not have given in the primary interview.

Findings

Responses to the student survey were downloaded from the online repository and sorted by question. The data collected during the student interviews and hands-on experience was transcribed, organized, and divided into categories such as pictures from the study, interview answers, scanning calibration times and others.

Survey Responses To assess which curriculums could be targeted for RE implementation it was important to ask students their major, to determine what type of distribution was present to assess what curriculums should be targeted for reverse engineering implementation. Table 2 contains the number of students in each major and the percentage of the entire course enrollment that major accounts for. Together Mechanical Engineering (ME) and Aeronautical and Astronautical Engineering (AAE) made up approximately 79% of the course. The other 21% is comprised of other engineering majors, technology majors, and some undecided or unspecified majors.

Students were asked 10 questions in total ranging from interest in RE, and their major, to their thoughts on RE incorporation. Of these 10 questions the four that held the majority of the focus in this study were:

1. Did you have any knowledge of RE prior to the study?
2. What is the preferred method of learning would you want an RE course to be based upon (i.e. text-based or hands-on)?
3. Would you like RE incorporated into your engineering curricula?
4. Do you feel visualization and spatial ability are important in RE?

Table 2

Enrollment Distribution by Major

Major	# of Students	% of Total Enrollment
Mechanical Engineering	202	59.59%
Aeronautical and Astronautical Engineering	68	20.06%
Aeronautical Engineering Technology	27	7.96%
Engineering (Unspecified)	19	5.60%
Mechanical Engineering Technology	8	2.36%
Electrical Engineering	3	0.88%
Aviation Technology	3	0.88%
Civil Engineering	3	0.88%
Acoustical Engineering	3	0.88%
Industrial Engineering	1	0.29%
Agricultural and Biological Engineering	1	0.29%
Undecided	1	0.29%
TOTAL	**339**	**100.00%**

Students gave a variety of answers when asked if they had any knowledge of RE prior to the study and associated lectures. For representation purposes the answers were separated into three categories. These categories were yes and had completed RE projects before, yes and just had basic knowledge of RE, and no knowledge prior to lectures. The graph in Figure 5 displays the percentages of each category.

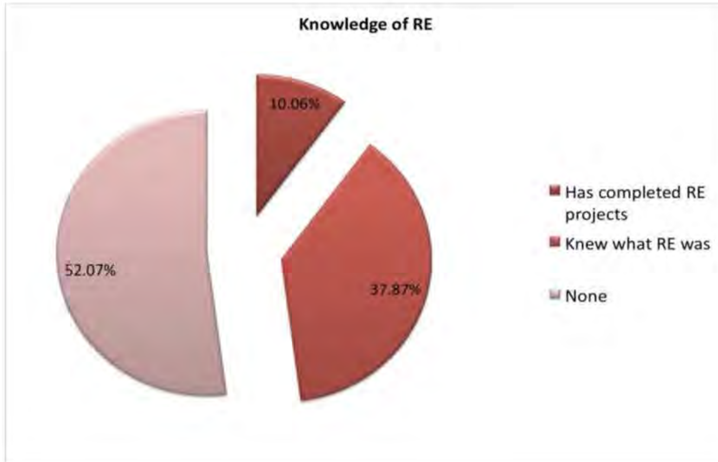

Figure 5. Student knowledge of RE

When creating or implementing any type of information into a course or curriculum it is important to keep in mind that the variety of students brings a variety of preferred learning styles. Some students learn better from reading textbooks or other text-based materials; other students learn best from using hands-on approaches in their studies. There are also many students that learn best from a mixture of both methods. As can be seen in Figure 6 not all students styles are the same.

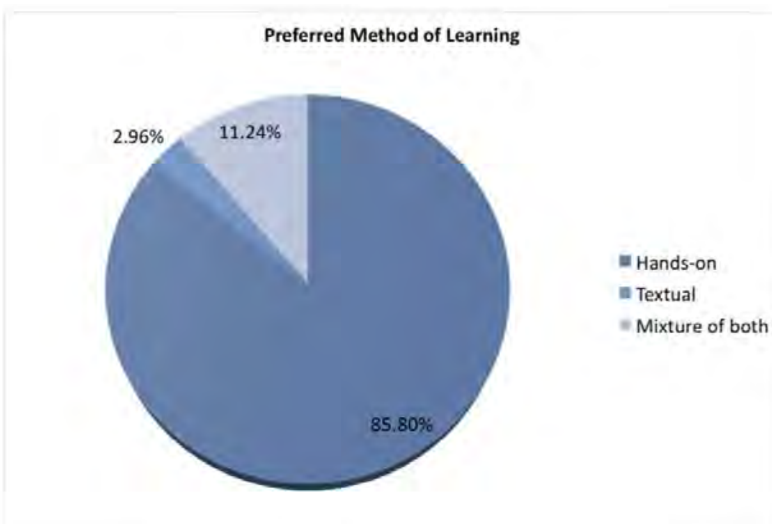

Figure 6. Student preferred method of learning

A focus throughout this study was to determine whether or not students would like to have RE methodologies incorporated into their engineering curricula. The answers to the question of whether or not students would want RE in their courses can be seen in Table 3. Over 80% of the students who completed the survey would like to see RE in their classrooms.

Table 3

Students' feelings on RE Incorporation

	Yes	No	Maybe	Not Sure	Total
# of students	278	34	16	7	335
%	82.99%	10.15%	4.78%	2.09%	100.00%

The last survey question focused on was whether or not students felt spatial ability and visualization is a necessary characteristic of the RE process. Some students felt that visualization plays a large role in the RE process while others did not. Other students felt that whether or not visualization was important depended upon the situation in which RE was encountered. The graph shown in Figure 7 provides a breakdown of the varied responses received from students.

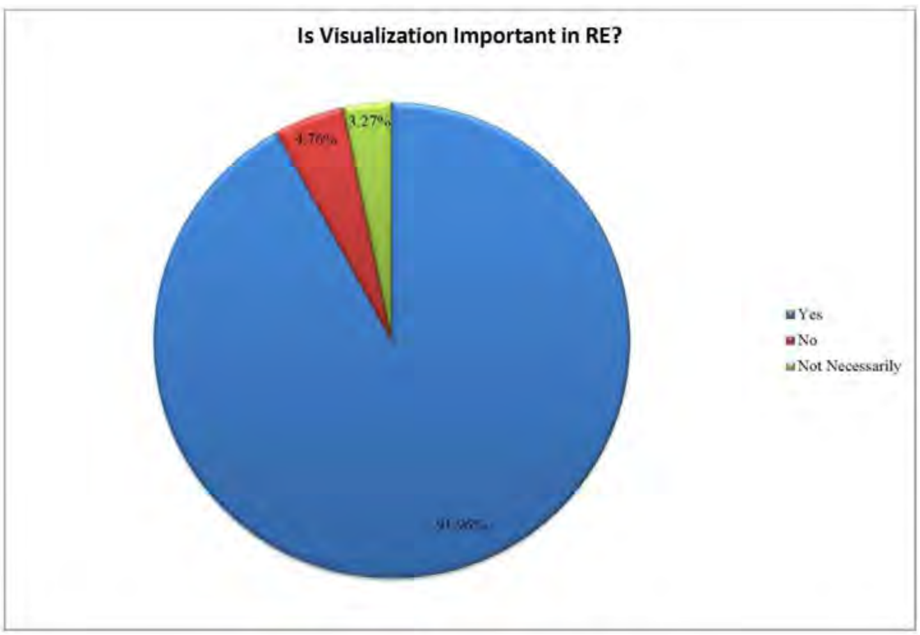

Figure 7. Student opinions on visualization

Not all responses gathered from student surveys were valid. Responses from students that included only the major and no other responses, student surveys that submitted a survey but failed to fill in any of the criteria, and surveys with inappropriate responses were discarded from the study prior to organization and analysis.

Hands-on Learning Experience As stated before the second portion of this study consisted of a hands-on experience where 10 students were given the opportunity to complete a short exercise using a 3D scanner. During the study students' calibration times were recorded.

Calibration times, PSVT-R scores, and spatial ability classification are shown in Table 4. These were collected merely to compare how students that were classified with low spatial ability levels matched up against those that were determined to have high spatial ability levels.

Table 4

Students' Scores and Calibration Times

Student	PSVT Score	Spatial Ability Classification	Calibration Time
0101	6	Low	1 hour 7 mins 46.53 secs
0323	7	Low	53 mins 37.37 secs
0423	10	Low	34 mins 5.87 secs
1020	10	Low	32 mins 31.73 secs
0421	12	Low	14 mins 24.71 secs
0417	36	High	4 mins 46.92 secs
0124	36	High	13 mins 5.62 secs
1021	36	High	5 mins 6.35 secs
1521	36	High	3 mins 0.34 secs
1524	36	High	7 mins 3.49 secs

Immediately following the scanning exercise the researcher conducted an interview with each student that participated. As stated earlier the interview followed five main categories including the 3D scanner tutorial, the calibration process, the scanning process, the course, and the study they had completed. Of the questions asked during the first interview there were two main questions to be focused on.

1. What factors do you feel must be taken into account if RE technology is incorporated into engineering curricula?
2. Do you feel spatial ability helped you in completing this process?

The first question was chosen because the main focus of the study was to determine what factors students felt need to be considered when incorporating RE methodology into engineering curricula. The second question was chosen to see if there was a relation between spatial ability and the 3D scanning process. These two questions were repeated later in the interview in a different phrasing to see if their answers were consistent and to allow for additional information they may have thought of while completing the interview. Randomly selected answers from student responses are listed below for each question.

Question 1, what factors do you feel must be taken into account if RE technology is incorporated into engineering curricula?

0101 – Cost is important because the scanner is expensive and CGT 163 has many students so we would need to figure out how the scanner would be used. Secondly, the scanner itself because it was heavy and the lectures were too short to explain the whole concept so additional lectures would be helpful. The last thing would be whether or not students are interested in learning about RE.

1521 – Honestly I do not know if everyone would be able to use a 3D scanner due to the hand eye coordination that is involved. Having tutorials for the scanning process would be helpful or possibly having an electronic version of the tutorial. The biggest factors are the expense of the equipment and the safety of the equipment. The more people you have using the equipment the more risk there is to it being damaged.

0423 – I feel the instructors would need to demonstrate the equipment and how to use it. I think for the RE tasks we need to have a step by step process. I think instructors should emphasize the importance of using it. They should talk about interesting aspects to attract students to using it and have information sessions about it. Cost is important because it is unlikely that all students can use one machine. Also, the instructors can assign some research assignments so that students can be familiar with it before-hand.

Question 2, do you feel spatial ability helped you in completing this process?

0323 – Yes, especially during the calibration process. I feel that it was at the level that was needed for the scanning process.

1021 – To some extent for the part of how reverse engineering works and how they take the scan into a model. I think my spatial ability needs to be more advanced to complete the process. It was the first time so I need to learn it more and with a complex part it will be more time consuming.

0417 – I do. The ability to be able to see what I was doing helped a lot. There were times I was not even looking at the scanner because I just knew where everything was with spatial ability.

The second interview was conducted on a different day following the completion of the scanning exercise. During the interview students were asked questions that were similar to those of the first interview in addition to questions about the RapidForm software. Student responses to those questions were also randomly chosen.

Question 1, what factors do you feel would need to be considered when incorporating RE methodology into engineering curricula?

0124 – I think the first thing is cost because the scanner seems to be expensive. Student experience should also be taken into account because some students may not be good at it. Instructors also need to find materials for the technology so that students can also learn about it.

1524 – Student experience because after the professors and teaching assistants know the feelings from the students they will know how to develop the course and make it better. I think experience is important because you need to learn it and try to figure out how to use it and get more experience of building a model in a short time.

0421 – Cost is an important factor but not time because the machine is easy to use. The time spent outside of lab to create assignments is pretty high but using this machine would decrease that. The students should be given a basic idea of what reverse engineering is like and the machines that are used.

Question 2, do you feel RE methodology will help with your professional growth?

1020 – Yes it will because I want to go into the engineering field and it is basically trying to take a product and figuring out how to make it better.

0323 – Yes it will. We are all engineers and doing mechanical engineering will help make designs better. This will help learn from mistakes that previous designers made in order to make it better.

0423 – Yes because in the future I need to do some more complex projects. To do the project I need to analyze which step I should start with and think of the most efficient method to do the project. I think reverse engineering will help me to do that.

As stated earlier there were many other questions that students were asked during their interview process. These questions were chosen merely for their importance to the study. After doing this study all 10 students expressed their interest in RE stating that it was interesting and fun.

Discussion

Over the course of the study students gave informative and detailed answers about many aspects of RE. With over 79% of the course being comprised of ME and AAE majors it can be concluded that those curricula would be those where RE would be the most useful if incorporated into the courses. Because RE is a process for mechanical parts it stands to reason that the students that would receive the most benefit would be those in mechanical focused areas.

When asked if they had any knowledge about RE prior to the study over 50% of students had no knowledge of what it was or what it entailed. By introducing students to RE they may become more informed about processes that are used in industry which could help with their professional growth. Among students that had heard of RE roughly 10% had actually completed some type of RE project.

Of the approximate 82% of students that would like RE incorporated into their curricula roughly 85% felt that a hands-on project based approach would be the most beneficial in their learning of RE methodology and processes, “Hands on material is much more valuable, because you will actually remember something that you did rather than what you saw in a slide.” Below 3% of students felt that text-based learning would be more beneficial. Among the 10% of students that would not want RE incorporated into their curricula reasons included not wanting any additional work to do because they already felt overwhelmed, feeling it would not be important to their future careers, or just simply were not interested in what RE is. As stated by one student, “No, I’m already going to be here for 5 years, don’t need more required credit hours.”

During the study over 90% of students felt that spatial ability and visualization is important in the RE process, “Ability to visualize is extremely important to use and implement RE technology so you can understand what exactly is going on.” Students felt that course assignments such as creating orthographic drawings from isometric images or isometric images from orthographic drawings would be beneficial when it came to reverse engineering a product. The ability to determine what they were looking at, how to maneuver the product, and being able to visualize what needed to happen were all characteristics that students felt would be a necessary part of RE.

The hands-on learning exercise gave students the opportunity to use the 3D scanning machine. Of the 10 students that participated in the scanning portion all 10 felt that the process was enjoyable and would take a class involving RE. One student responded, “Yes because you can just understand products a lot more when you reverse engineer it. Then actually putting it back together you will understand how it works and apply it to other businesses you may get involved with.” Gathering students’ opinions of whether or not they would enroll in a course involving RE informs faculty as to the amount of student interest there is in this field.

Answers varied when asked about what factors they felt needed to be considered when incorporating RE into engineering curricula. The factor students felt was the most important was “cost.” Because the equipment they were using was so expensive they felt the ability to have every student use the scanner would be practically impossible and that it would be very expensive to purchase more 3D scanners for the university. Other factors that students felt were important were maintenance of the equipment, student and faculty training on the equipment, liability if the equipment is damaged, the weight and handling of the scanner, student experience, safety, and spatial ability. These are all of the factors that students feel would be important if RE was incorporated into their engineering curricula.

Conclusion

Introducing students to the multiple applications of RE gave a broad understanding of RE, what it helps to accomplish, and how it works. The ability to introduce students to 3D scanning, by gathering data from a 3D surface allowed students to examine a technology that not many universities possess (Sokovic, Cedilnik, & Kopac, 2005). When students were taught about RE methods 82.99% stated they would like RE implemented into their curriculum. Also, after completing the hands-on learning exercise involving the 3D scanner all participants were much more interested in RE and said they would definitely take a class based on RE methodology.

As stated earlier students felt that cost, time, experience, and a few other factors would be important when incorporating RE into engineering curricula. Though 10 interviews is not a large sample, the interviews were able to provide additional insight into the results presented by the survey data. Spatial ability was also said to play an important role in RE according to the students who completed the 3D scanning exercise.

This study gave students information about RE, how it is used, and why it is important. Select students were given the opportunity to operate a hand held 3D scanning machine and 10 out of 10 students felt that it was an experience that not many students would get to experience in their careers. This study determined what factors students felt were important to the implementation of RE and gave students the opportunity to use a new technology that had just recently been acquired at the university.

Recommendations

A hypothesis going into the study was that students classified as having high spatial ability would complete the scanning calibration process more quickly than students who were classified as having low spatial ability. When monitoring student performance during the calibration process that hypothesis held true and an additional characteristic that was found was the connection of video games and calibration times.

When gathering information about student interest, students were asked if they played video games and if so what types of games they played. Of those that had played video games, first person shooter titles such as Call of Duty or Halo were the most popular. The students who played video games of containing 3D maneuvering such as the Call of Duty series had the lowest calibration times of everyone. Does interacting with video games involving 3D maneuvers improves one's spatial ability? To add to that additional research can be conducted to determine whether or not a person's spatial ability contributes to the 3D scanning process and whether that may play a role in the time it takes them to calibrate the scanning machine.

References

Hess, H.L. (2000). Teaching manufacturing using the golden key – reverse engineering. *ASEE conference proceedings, St. Louis, MO*. Retrieved from http://search.asee.org/search/fetch;jsessionid=6pmja0rrhm7c?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F24%2FAC%25202000Paper608.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Orta, P., Medoza, R.R., Elizalde, H., & Guerra, D. (2006). Engineering education through reverse engineering. *Proceedings of the ASEE Annual Conference & Exposition: Excellence in Education, Chicago*, 1-11. Retrieved from http://discover.lib.purdue.edu:3210/purdue?sid=EI%3ACompendex&issn=&isbn=&title=ASEE%20Annual%20Conference%20and%20Exposition%2C%20Conference%20Proceedings&date=2006&volume=&issue=&spage=&epage=&aulast=Orta&aufirst=Pedro&atitle=Engineering%20education%20through%20reverse%20engineering

Sirinterlikci, A., & Mativo, J. (2010). Teaching reverse engineering for non-industrial applications. Paper presented at the *117th Annual Conference and Exposition of the American Society for Engineering Education (ASEE 2010),* 1-8. Retrieved from http://search.proquest.com/docview/839639712?accountid=13360

Sokovic, M., Cedilnik, M., & Kopac, J. (2005). Use of 3D-scanning and reverse engineering by manufacturing of complex shapes. *Proceedings of the 13th International Scientific Conference on Achievements in Mechanical and Materials Engineering*, *Gliwice-Wisla, Poland,* 601-604. Retrieved from http://www.journalamme.org/papers_amme05/1418.pdf

Tang, D., Zhu, R., & Xu, R. (2010). Functional reverse design: Method and application. In W. Shen, N. Gu, T. Lu, J.P. Barthès, J. Luo (Eds.) *Proceedings of the 2010 14th International Conference on Computer Supported Cooperative Work in Design.* Shanghai, China, 723-727. Retrieved from http://ieeexplore.ieee.org/Xplore/login.jsp?url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F5466608%2F5471868%2F05471882.pdf%3Farnumber%3D5471882&authDecision=-203

Wood, K.L., Jensen, D., Bezdek, J., & Otto, K.N. (2001). Reverse engineering and redesign: Courses to incrementally and systematically teach design. *Journal of Engineering Education, 90*(3), 363-374. Retrieved from http://search.proquest.com/docview/217940865?accountid=13360

Open-ended Project Learning Experience in Graphical Communication

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Abstract

This paper includes the implementation of Bloom's taxonomy in the introduction to graphical communication course and shows how students are moved up Bloom's taxonomy by changing previous guided individual final project to open-ended projects. Instead of following the instructor's direction to complete the model design, students are required to research the product they want to design, and build the model by themselves. The open-ended projects enable and challenge students to work on higher level of Bloom's taxonomy by emphasizing design creativity, exploring real engineering design problem, and enhancing their oral and written skills.

Introduction

Bloom's taxonomy is a commonly accepted taxonomy of cognitive skills developed by Benjamin Bloom (1956), which is based on the level of student understanding necessary for achievement or mastery. The system can be used to evaluate the objectives of the course curriculum and class activity. Introduction to Graphical communication is one of the largest classes taught in Freshmen Engineering Department at Embry-Riddle Aeronautical University, with an average enrollment of 500 students a year. The course is designed to familiarize the student with the basic principles of drafting, engineering drawing, improve three dimensional visualization skills, and fundamentals of a computer aided design program-CATIA. Much of the teaching is focused on the knowledge and comprehension, low levels of Bloom's taxonomy. Instructor shows students step by step how to understand principle of orthographic projection, section, auxiliary views, dimensioning, tolerancing, build a model and make sure they can follow and understand the procedure. But their ability to use knowledge and comprehension to explore real engineering design is unknown.

In the 1950s Benjamin Bloom and his colleagues formulated a classification system of educational objectives based on the level of student learning. Researchers discussed the six levels of the Bloom's taxonomy including Felder (2004) and Jones (2009):

1. Knowledge. Recalling material you have learned.

2. Comprehension. Demonstrate the understanding of the terms and concepts.
3. Application. Apply the learned information to solve the problem.
4. Analysis. Break things apart so that relationships are understood.
5. Synthesis. Put together parts to form a new whole.
6. Evaluation. Make critical judgments, rate ideas or objects and to accept or reject materials based on standards.

Our current curriculum gives students much practice in the low levels of knowledge, comprehension, and application. Students do not have opportunities to practice their analysis, synthesis, and evaluation skills, which can enhance their thinking and creative skills and enable them succeed in today's competitive engineering environment.

This paper includes the implementation of Bloom's taxonomy in the introduction to graphical communication course in the spring and the fall semester of 2011, and shows how students are moved up Bloom's taxonomy by including more challenging assembly projects into the course. Instead of following instructor's direction to accomplish an individual design project, students are required to accomplish one individual airplane project and one team-based project. To the airplane project, students can choose whatever airplane they want to design and finish the assembled airplane in 3 weeks. After they finish the airplane project, they will start their team-based project. They need to research the product they want to design, build the assembly product, and present their work at the end of the semester. Since 90% of students are freshmen who study aerospace engineering, it is believed that by designing an airplane it will enhance their understanding of airplane structure and aerodynamics mechanism. Team-based project enables and challenges students to work on highest level of Bloom's taxonomy by emphasizing teamwork, exploring real engineering design problem, judging the design criteria, and enhancing their oral and written skills. An end-of-semester survey was implemented to collect student's feedback regarding the two projects initiation. The results suggest that taking Bloom's Taxonomy into account in course design is worthwhile.

Current Curriculum and Course Structure

The goal of the Graphical Communication course is to familiarize the student with the basic principles of drafting, engineering drawing, improve three dimensional visualization skills, and fundamentals of a computer aided design program. After the completion of the course, students will know the character and application of the various lines used in engineering drawing; be able to relate a scaled drawing to actual size and be able to produce drawings to scale; develop the ability to make acceptable freehand sketches with special understanding of the importance of proportions; know the principles of orthographic projection and apply these principles to construct multiview drawings; understand the principles of isometric projection and apply these principles to isometric drawings; understand and draw auxiliary views; understand and draw interior view of an object as a section view; develop the techniques and rules of dimensioning and tolerancing, and be able to apply these skills to a drawing; be able to read and understand basic blue print; be able to understand and use CATIA as a computer aided drafting tool to produce multiview, isometric, auxiliary and section views.

As a 3-credit course, students meet the instructor twice a week. Each class lasts 2 hours long. The first hour is the scheduled lecture time. After the lecture, students are allowed to use the rest of class time to ask questions and complete their assigned homework. During the 14-weeks semester, students will learn the principle of the orthographic projections and apply the principles to multi-view drawings by hand in the first 4 weeks. After it the introduction to CATIA-a 3-D computer aided drafting tool will be introduced and followed by the auxiliary views, section views, dimensioning, and tolerancing. A common final individual assembly project as an application under the direction of the instructor will be given to the students to test their problem solving skills. Normally students need to complete at least 10 parts and assemble them following the constrain requirements. Figure 1shows the exploded and 3-D view of previous individual project respectively.

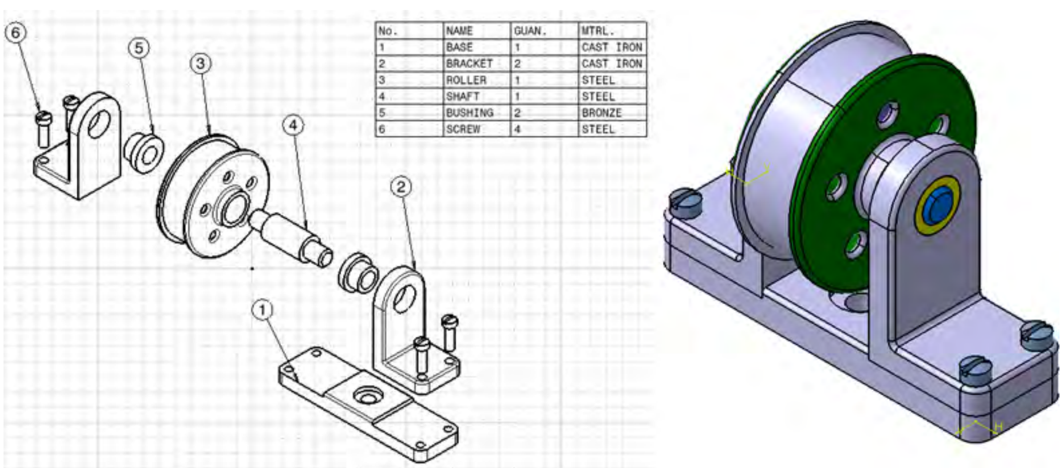


Figure 1. Exploded view of the roller guide and 3-D view of the roller guide

From the end of course evaluation, we learned that students could follow the direction and accomplish the individual project on time. But they felt a guided project was lack of challenge and they would like to design a more complex model by themselves. According to the Bloom's taxonomy, a guided individual project is considered as an application, which can be used to test student problem solving ability and satisfy ABET requirement. However, at this level students could not transfer material learned in the classroom into real life situations as discussed by Farris and Lane (2005). They would be more frustrating when they are confronting an open ended design. To change this situation, starting in the spring semester of 2011, an individual open-ended airplane project and an open-ended team design project were initiated. To the airplane project, students need to design the airplane wing and jet engine following the instructor direction, after it students will accomplish the rest of the parts and assemble their own airplane. The design is evaluated by the level of the complexity by the instructor and the teaching assistant. This level is considered as the synthesis level according to Bloom's taxonomy. To the team-based project, students can choose design topic and form a team of 3 or 4. They are expected to use considerable skills learned in the class or by themselves to achieve their own goals with minimum assistance from their instructor. Their design is evaluated by their peers, and the instructor against a defined specification. This level of study is considered as the highest level of the Bloom's taxonomy-evaluation. It is expected that students could transfer the classroom learning to real situations after the completeness of the final project.

Project Outcomes

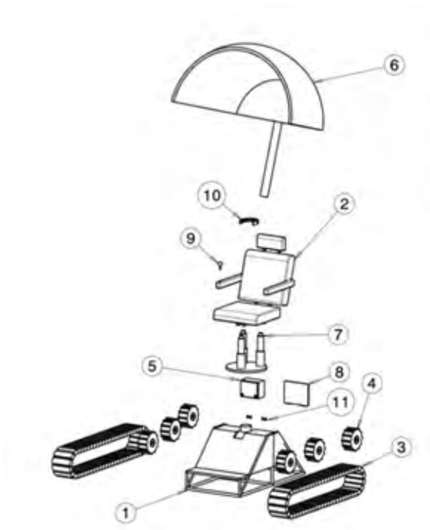
There were 26 students enrolled in the spring of 2011 and 35 students enrolled in the fall of 2011. To the airplane project, students were given three weeks before they started the team-based final project to design their own airplane. After they learned how to build the airplane wing and the jet engine by following the tutorial given by the instructor, they were on their own to explore the different tool bars or icons by themselves to accomplish this project. Figure 2 shows the rendered pictures of student designs. Since this is an open-ended project, students can be creative and learn more as they desire.

Figure 2. Rendered airplane model

To the team-based project, as a team of 3 or 4, they were able to choose their design partners and finished their design project within 3 weeks. The teams need to first present their design idea to the instructor and the idea must be approved by the instructor to make sure that each team has a unique design product and there is no duplicate design. Students must do a certain amount of research to include the up-to-date technology in their product to emphasize the eco-friendly design and cost efficiency. The product must involve the new design and is not available in today's market. Each assembled product needs to include at least 10 parts. Each part is designed individually. The role of the instructor is a facilitator to ensure student projects delivered on time and the guidance is limited to the minimum. All dimensioned drawing sheets, 3-D part models, and power-point slides must be submitted on the Blackboard before the beginning of the last day of the class. On the last day of the class, students dressed up to present their work as a team. Each presentation lasted 8-10 minutes long and followed by 2-minutes Q&A time. Peer evaluation and team evaluation forms were given to the students to evaluate their peers work, and team presentation work. At the end of the presentation, instructor would summarize and conclude student projects. A survey was implemented to collect student feedback regarding their satisfaction of the final project and their comments on how to improve the delivery of the final project. During the two semesters, there were totally 16 projects designed by 60 students. The project topics are listed in the Table 1. Figure 3-4 show the exploded view and 3-d view of student team projects. The projects students finished are listed in the table 1.

Table 1. Student Project List

Eco-friendly Skateboard	**Sun-go Skate**	**A future bicycle**	**Jet engine powered bicycle**
A better keyboard	CAD mouse	A perfect office chair	Space Relay Power System
A rocket board	Light year Jetpack	Eco Cruiser	Hover board
Self-powered elliptical	Hovercraft	Solar powered wheelchair	Plasma propelled Spacecraft



NUM.	PART	QUAN.
1	CHASSIS	1
2	CHAIR	1
3	BELT	2
4	GEAR	6
5	BATTERY	1
6	SOLAR UMBRELLA	1
7	LIFT	1
8	BATTERY DOOR	1
9	JOYSTICK	1
10	HEADSET	1
11	SCREW	8

Figure 3. Exploded view and 3-D view of solar powered wheel chair

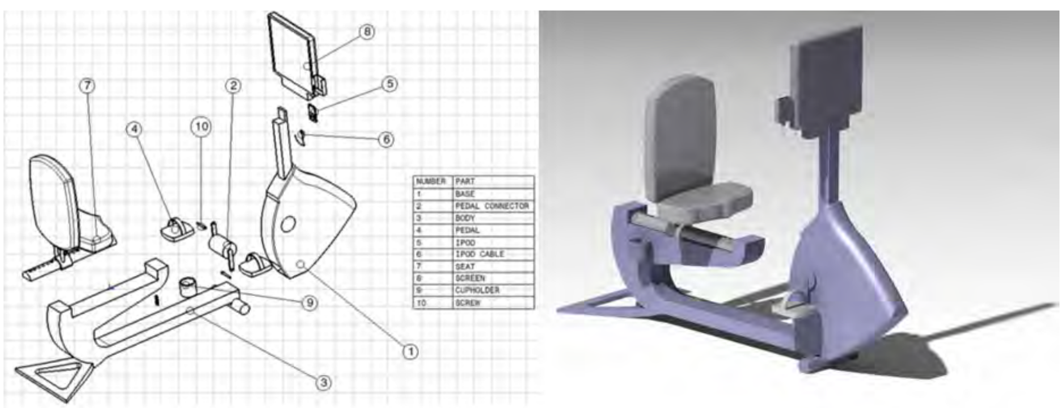


Figure 4. Exploded view and 3-D view of solar powered wheel chair

ASSESSMENT

An end-of-semester survey was implemented to collect student's feedback regarding the open-ended project initiation. In spring and fall semester of 2011, there were 37 out of 61 students who filled out the survey at the end of the semester. Figure 5 shows the airplane satisfaction analysis in spring and fall semester of 2011. Since the majority students are aerospace engineering major, the airplane design was greatly welcomed by the students. Overall over 85% students like the airplane project and only 1 student showed the unlikeness in the two surveys. Some student responses are shown as follows:

- It is pretty much a perfect opportunity for students to put their knowledge into this exiting project.
- More knowledge of CATIA to make the plane more detailed.

- A bit more time to do it.
- The grading rubric.

From student response we can see that they are eager to learn more and design a better airplane, even though as an introductory level course the content of CATIA covered in the class is restricted by the limited class time.

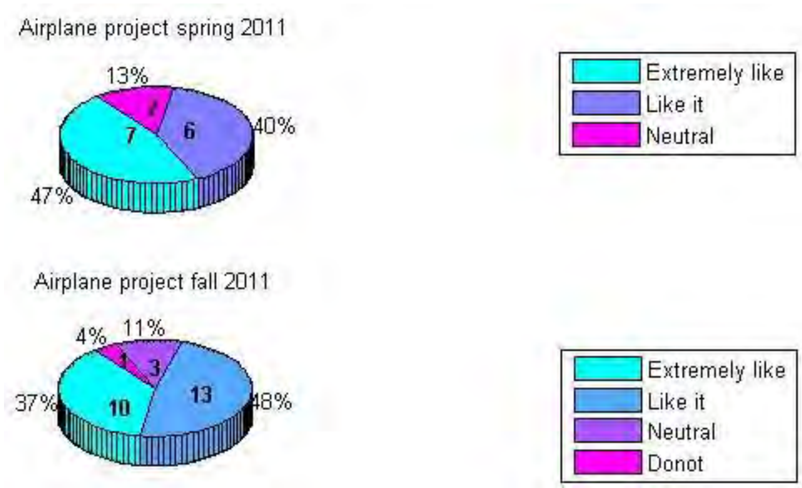


Figure 5. Two - semesters final project satisfaction analysis

Final project satisfaction data was analyzed in the Figure 6. From the chart we can see that the majority (37/42) of students enjoyed the final project design. Students highly rated the final project as a chance to understand an engineering design process. They enjoyed designing their own product, working with different classmates, and challenging themselves. They believed that they learned more from the final project by exploring tools which was not covered in class time, teaching themselves the communication skills, working as a team, enhancing their presentation skills. The main complaint was the limited time assigned to the project. Since there were only three weeks left for the project, they felt they can do much better if more time could be assigned. Some student responses are shown as follows:

- I enjoyed the fact that we got to choose our own topic for the final project. I enjoyed choosing something that was interesting to me but that was also challenging.
- It was cool to work with new people and build something new.
- I liked it, thought it was interesting.
- The final project was great!
- More time so that students can create more complex products.
- More defined parameters as to what needs to be turned in and what is expected of the presentation.

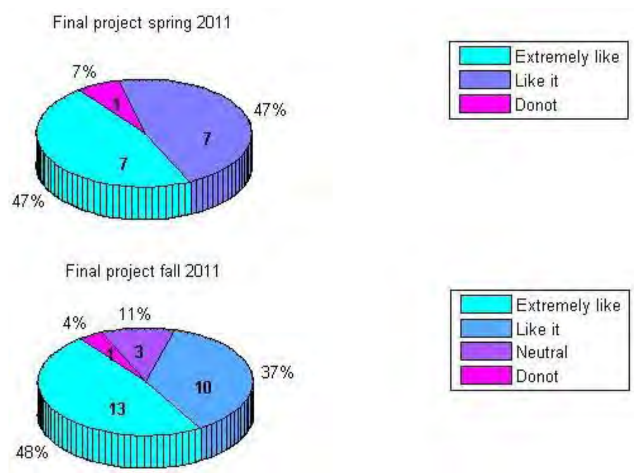


Figure 6. Two - semesters final project satisfaction analysis

Conclusion

This paper has presented a transition from a guided individual project to an airplane self-design project and a team-based design project by following Bloom's taxonomy. An end-of-semester survey was implemented to collect student's feedback regarding the open-ended project initiation. 61% students filled out the online survey. Students have responded positively to the two open-ended projects. It is believed that by teaching higher level of Bloom's taxonomy students would gain more solid knowledge and improve their ability to transfer the classroom material to real-life product design. Based upon student feedback, more time will be given to the students to produce more complex models. A revised project direction is needed to provide a detailed explanation regarding the submitted files and presentation expectation.

References

Bloom, B.S. (1956). *Taxonomy of educational objectives: Handbook I: Cognitive domain*. New York; Toronto: Longman.

Farris, J and Lane, P. (2005). *Reality Learning: Teaching Higher on Bloom's Taxonomy*, Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition.

Felder, R M. and Brent, R. (2004). *The ABC's of Engineering Education: ABET, Bloom's taxonomy, Cooperative Learning, And So On,* Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Session 1375.

Jones, K. O., Harland, R., Reid, J. M.V., and Bartlett, R. (2009). *Relationship Between Examination Questions and Bloom's Taxonomy*, 39th ASEE/IEEE Frontiers in Education Conference, Session W1G.

Dimensional Tolerances: Back to the Basics

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Abstract

Students often have difficulty grasping the principles of dimensional tolerances and frequently fail to recognize that dimensioning practice has a significant impact on the tolerance of part features. This observation may be attributed to several factors, not the least of which are changes in prior student education and life experiences and increasing pressure in academia to add course content to cover new technologies, sometimes at the expense of fundamental concepts. This paper presents some back-to-basics instructional methods designed to help students improve their understanding of tolerances, including a description of some hands-on instructional activities that were implemented in the Engineering Technology program at Illinois State University.

Introduction

The focus of the Engineering Technology program at Illinois State University (ISU) is to prepare technically-oriented management professionals for work in a variety of manufacturing-related careers. Few of our graduates are expected to make decisions regarding the appropriate tolerances for a given product, although many are expected to interpret part prints that include tolerance specifications. Accordingly, our focus is to provide instruction to help students develop the ability to interpret dimensional tolerances and help students develop an understanding of the relationship between dimensioning and tolerancing practices and the cost to manufacture a product.

In years past, many students came to the Engineering Technology program at ISU with prior hands-on shop experience obtained by working on the farm or in K-12 technology education classes. Today, however, seemingly few students come to ISU with experience physically making things with their hands, resulting in a student population that often has difficulty finding meaning in textbook discussions of tolerances. For example, a textbook discussion of full indicator movement (FIM) has little meaning to engineering graphics students who have never seen a dial indicator. Similarly, some students have difficulty appreciating the meaning of a tolerance callout of +/- .005" because they have never used a measuring instrument capable of measuring at that precision. Topics such as tolerance stacks and datum reference frames are abstract concepts to many students who often simply learn these concepts by rote rather than develop an understanding and appreciation for the tolerance-related messages expressed on part prints.

This paper will describe several hands-on group activities that have been added to an intermediate engineering graphics course at Illinois State University. The group activities require students to interpret a variety of dimensioned part prints and physically measure the parts they describe. Although all groups measure the same physical parts, different dimensioning practices were used on the part prints, frequently resulting in the parts being “good” for some groups but “bad” for other groups. Each group created inspection reports for their parts and was required to explain and defend their report to the other groups in the class. In some cases, the part prints were intentionally over-dimensioned to help students discover that this practice leads to conflicting tolerances and multiple interpretations.

Background

The ISU Engineering Technology Industry Advisory Board is comprised of 12 professionals working in a variety of manufacturing-related industries throughout the Midwest. One consistent theme discussed by ISU advisory board members is the importance of print reading and tolerance interpretation skills in the manufacturing workplace. Similarly, the literature is replete with work indicating that engineering and engineering technology students should receive instruction in the area of tolerancing concepts. For example, Meznarich, Shava, and Lightner (2009) presented the results of a study that indicated print reading and tolerance interpretation were seen as important topics by both industry professionals and educators. Lamb and Kurtanich (2007) describe the rationale and structure of a new course they developed at Youngstown State University to help improve instruction in various areas of print reading including tolerance interpretation. Evans (2004) describes an innovative approach to use standard CAD tools to “virtually” inspect products based on geometric dimensioning and tolerancing (GD&T) callouts. Sriraman & DeLeon (1999) describe their use of a coordinate measuring machine (CMM) to help improve instruction in the area of GD&T. In summary, based on input from our program constituents, as well as support from the literature, the engineering graphics curriculum at ISU was modified in 2010, allowing new instructional activities to be added in the area of dimensional tolerancing.

ISU Curriculum Changes

ISU Engineering Technology students are required to take two courses specifically dealing with engineering graphics and technical drawing. Until recently, the TEC116 course, Introduction to Technical Drawing, introduced students to the fundamental principles of technical drawing using primarily hand-sketching and 2D AutoCAD™. This former TEC116 course was designed to accommodate students from primarily two technical areas: engineering technology and construction management, and therefore had broad course content. Engineering Technology students then took a second required course, TEC216 Computer Aided Design and Drafting, in which they were introduced to the principles of constraint-based solid modeling, and a variety of manufacturing-related technical drawing topics including ASME dimensioning and tolerancing principles. The former TEC216 course schedule included two days of discussion dealing with traditional tolerancing topics and two additional days of introduction to GD&T.

Based on recommendations from our industry advisory board and program alums, several curriculum changes were implemented in 2010. A new introduction to construction graphics course was implemented to serve the specific needs of construction management students, and the TEC116 course, which is still required for engineering technology students, was significantly modified. The most notable change in TEC116 was the deletion of content dealing with 2D AutoCAD™ and the addition of 3D solid modeling content using Autodesk Inventor™. TEC116 students now receive a comprehensive introduction to constraint-based solid modeling during their first engineering graphics course. This change has had a dramatic effect in the TEC216 course because much of the time spent in previous years introducing students to the principles of solid modeling may now be spent covering other topics. The TEC216 course now includes expanded coverage of dimensional tolerancing principles. The remainder of this paper presents some of the instructional activities that have been added to the revised TEC216 course.

Activities to Support Basic Tolerance Concepts

Dimensional tolerance instruction in the TEC216 course begins with a discussion of tolerancing terms and concepts such as tolerancing formats, limits of size, and fits. The main focus of instruction at this point is on the fundamental concepts of traditional (+/-) tolerancing. After several calculation sheets and sample part prints had been worked through together in class, students were divided into small groups and given a simple machined part, partially dimensioned print (Figure 1) and a dial caliper. Students were then asked to use the dial caliper to measure several part features, complete an inspection report (Figure 2), and make definitive statements about whether the part features were in tolerance. Finally, groups were randomly selected to present their inspection results to the class. When opinions from the groups differed, the students were required to defend their findings.

To make things a bit more interesting, several features on the part prints were dimensioned differently and given to the groups. For example, the slot feature size and location (dimensions D, E and F in Figure 1) were intentionally dimensioned using different methods, resulting in students using different inspection methods to measure the slot. In some cases, several groups concluded the slot feature met specifications while other groups did not. Using different dimensions on the part prints resulted in several discussions regarding dimensioning practice and the designer's true intentions.

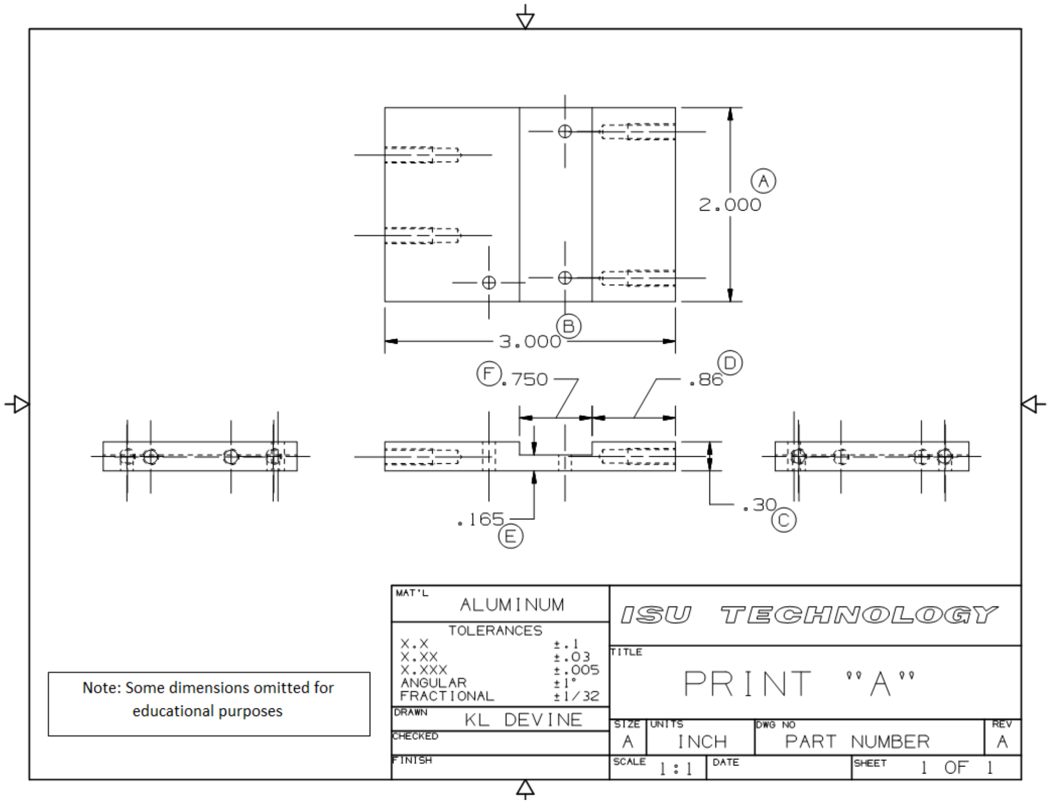
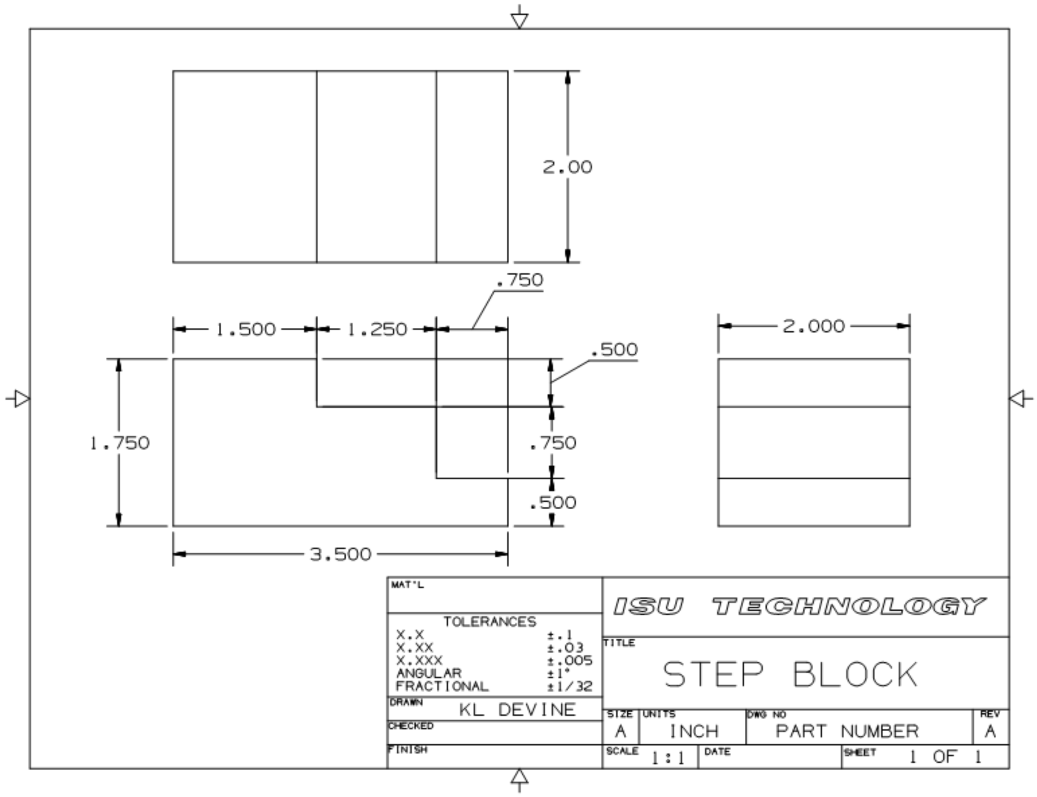


Figure 1. Sample part print.

Feature	Nominal	Actual	Deviation	Tolerance	Upper Limit	Lower Limit	Out Of Tolerance Amount	In tolerance?
A								Yes / No
B								Yes / No
C								Yes / No
D								Yes / No
E								Yes / No
F								Yes / No

Figure 2. Sample inspection report.

After physically measuring two parts in small groups, students were required to complete several tolerance calculation exercises using only part prints. Although these exercises have been completed in the TEC216 in previous semesters, a noticeable improvement in student performance was observed, and in-class discussions on these exercises involved more students this semester. This semester, a simple part print that was intentionally over-dimensioned was given to the students (Figure 3). This problem created quite a bit of discussion as students discovered there was more than one way to calculate the limits of size for this part. While students had previously been told that over-dimensioning is poor practice, several students commented that the exercise helped them understand why this practice is not acceptable, especially when they were pressed to complete the simple tolerance table that accompanied the print.



Based on the print above, complete the following table:

Feature	Nominal size	Tolerance	Maximum Limit of Size	Minimum Limit of Size
Overall length				
Overall height				
Overall width				

Figure 3. Sample over-dimensioned print.

After spending two class periods measuring parts using dial calipers and completing print reading exercises and calculations sheets, students were required to measure two parts using a coordinate measuring machine (CMM). Working in small groups, the students were guided through the process of measuring various part features to create a computer-generated inspection report identical in format to the report illustrated in Figure 2. These CMM measuring activities helped students better understand concepts of measurement accuracy and helped set the stage for some future GD&T measurement activities.

Hands-on Activities to Support GD&T Concepts

Instruction in GD&T principles took place after students had completed the activities described above. By this point in time, students had been exposed to basic concepts such as maximum material condition (MMC), least material condition (LMC), fits, and the like. The students had also experienced print reading and simple part inspection using a dial caliper and a CMM.

GD&T instruction started with an introduction to feature control frames and symbols, tolerance zones, and the datum reference frame. Several textbook exercises and in-class feature control frame exercises were conducted to help students learn about the basic language of GD&T. Several hands-on activities and demonstrations were added using hand-measuring instruments to augment the textbook-based instruction. For example, students were shown how to use a dial indicator, height gage, and surface plate to measure a part surface. By using these tools, students gained a better understanding of the tolerance zones being described by various feature control frames. Other instruments demonstrated included gage blocks, sine bars, and vee-blocks.

Students were then given simple machined parts and prints containing GD&T callouts. The students were first required to interpret the datum reference frame and feature control frame callouts (limited to true position). Tolerance zones specified by the feature control frames were hand-drawn on the print and a CMM inspection plan was created to measure the required physical part features. Next, a sample part was loaded on the CMM and students were instructed how to use the CMM software functions to implement their inspection plan. The graphics capabilities of the CMM software allowed a CAD solid model of the part to be opened and displayed. This feature proved to be very helpful when establishing the datum reference frame because the software displayed the frame using the same coordinate system triad (XYZ axes) used by most CAD systems. Figure 4 illustrates a simple part that was measured by the students.

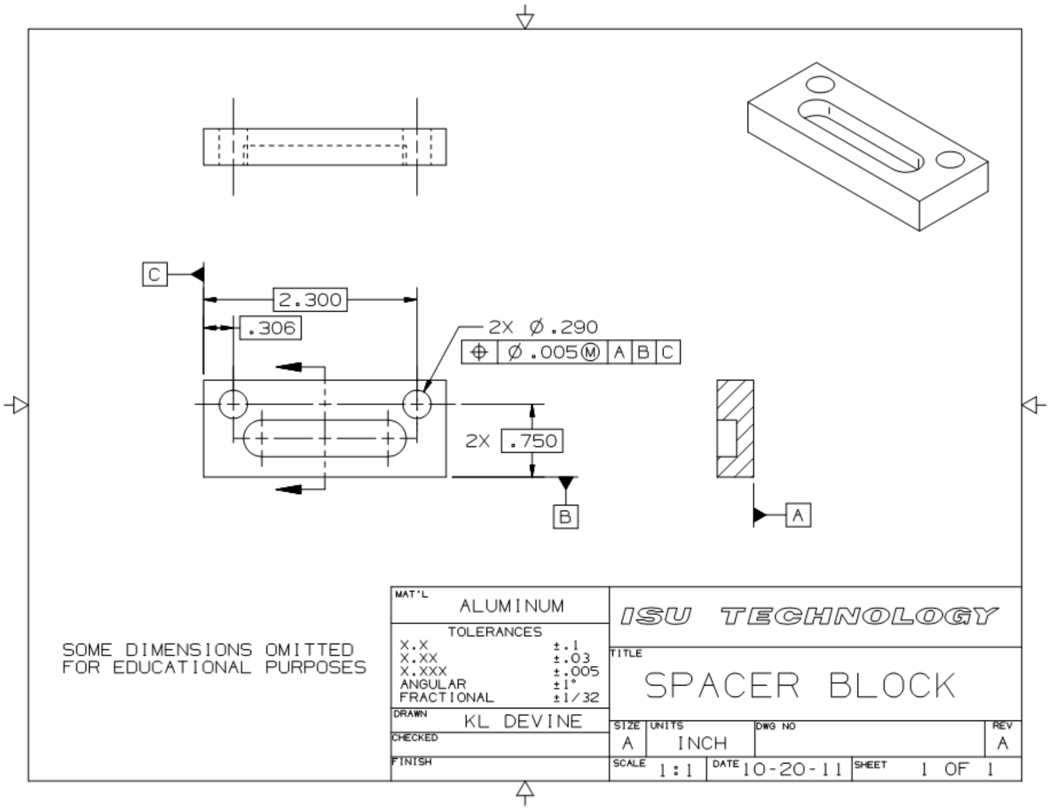


Figure 4. Sample GD&T print.

Conclusions

Although the changes to the engineering graphics courses describe above were implemented at ISU during the Fall 2010 semester, the impact of the changes were not seen in the TEC216 course until the Fall 2011 semester. As expected, the curriculum change freed up some time in the TEC216 course to allow for additional instruction in several areas including dimensional tolerancing.

Engineering Technology students seem to learn best by putting theory into practice. Therefore a priority was placed on adding hands-on activities in the TEC216 course in the area of dimensional tolerances. The hands-on measuring activities added in TEC216 seemed to help ground the abstract tolerance concepts into knowledge that students can better understand and use. The activities were not difficult to design and implement and although the activities described in this paper included the use of a CMM, other activities utilizing less expensive measuring instruments could be developed in their place. While the activities themselves seem somewhat simple in nature, they proved to be very beneficial to student learning. Anecdotal comments from students as well as overall performance in the class suggest the activities were well received by the students and helped improve student understanding of dimensional tolerances. In a time when educators are often pushed to add new technology to their courses, sometimes a back to the basics, hands-on approach should be considered.

References

Evans, E. R. (2004). Solid Models, Virtual Inspection and the Position Tolerance. Proceedings from the 59th Annual Midyear Meeting of the American Society for Engineering Education/ Engineering Design Graphics Division (ASEE/EDGD), Williamsburg, VA.

Lamb, C. M, Kurtanich, D. G (2007). Drafting the Basics. Engineering Design Graphics Journal, 71(3), 35-44.

Meznazrich, R. A., Shave, R. C., & Lightner, S. L. (2009). A Curriculum Model: Engineering Design Graphics Course Updates Based on Industrial and Academic Institution Requirements. Engineering Design Graphics Journal, 73(2), 31-41.

Sriraman, V., DeLeon, J. (1999). Teaching Geometric Dimensioning and Tolerancing in a Manufacturing Program. Journal of Industrial Technology, (15(3). 2-6.

Factors Facilitating the Need for a Visual Graphics Animation Baccalaureate Degree at a Mid-South University

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Abstract

The purpose of this study was to determine if a Visual Graphics Animation four-year baccalaureate degree should be offered in the mid-South. For the purpose of the study, the mid-South was defined as the states of Alabama, Arkansas, Illinois, Louisiana, and Mississippi. The selection of the states was based on the location of EAST Initiative programs. However, high school graduates not involved with the EAST Initiative also show a strong interest in obtaining an animation degree.

The EAST Initiative has been educating high school students for the past 16 years. The EAST model is grounded in solid pedagogical theory related to the use of technology as a catalyst for learning, collaborative learning, and performance-based learning. There is a growing need for the EAST students and others to obtain an advanced degree in the emerging technologies. One of the technologies is animation that can be applied to many different occupational areas, i.e. business, education, engineering, films /movies, games /gaming, geographical information systems, law/forensics, and medical.

The research revealed interest in the field of animation from current and past EAST graduates. Facilitators report that students are willing to travel as far as it takes to receive a quality four-year degree in Visual Graphics Animation. The results show a strong field of prospective students that could be recruited into a four-year degree from the mid-South region. The recommendation from this study is that a college or university located in the mid-South region could develop a successful and productive program of study in Visual Graphics Animation.

Introduction

For the past 16 years, the Environmental and Spatial Technologies (EAST) Initiative has engaged students in an educational environment steeped in emerging technologies and focused on self-direction and community service. The EAST Initiative is supported by a dynamic collaboration of government, education, and business partnerships that share a common goal of striving to make a difference in the lives of children and their communities (Environmental and Spatial Technologies, 2005).

The EAST Initiative has expanded to over 200 schools in 7 states including Alabama, Arkansas, California, Hawaii, Illinois, Louisiana, and Mississippi (EAST, 2005). The success rate of employment in the animation field has been accelerated by this organization. Students not involved with the EAST Initiative are also showing a strong interest in animation (Gibbs, 2005). However, the high school graduates are leaving the mid-South to find educational opportunities and employment in their selected animation fields. Ross DeVol, director of regional economics at The Milken Institute, told the annual Arkansas Venture Capital Conference, "Arkansas is one of the top exporters of talent in the country" (Zehr, 2004).

One of the main requirements for employment of college graduates in the mid-South is a four-year degree rather than a two-year degree according to data contracted by the Arkansas Department of Workforce Education (Arkansas Department of Workforce Education, 2005). High school graduates are leaving the region to obtain four-year degrees in animation, video graphics, filmmaking, and/or digital art. After obtaining their degrees, the students are remaining in areas near the four-year institution due to employment opportunities.

There are no advanced degrees offered in the area of animation, video graphics, filmmaking, or digital graphics in the mid-South states that support the EAST Initiative (Alabama, Arkansas, Illinois, Louisiana, and Mississippi). *Animation Magazine* school guide for 2004 lists two- and four-year degrees offered in the world. In the United States, the leading states offering digital graphic degrees are California, Georgia, New York, Florida, and Minnesota. California has more schools than all the other states combined (School Guide, 2004). With the advancement of technology, it is no longer necessary to relocate to California to be involved with the movies. Movies can be created anywhere there is a high-end computer loaded with graphics software. It makes good economic sense to keep our graduates local and provide high tech jobs in our mid-South area.

Review of Related Literature

Walt Disney has been creating animation for years (Walt Disney Studios, 2004). At one time or another, people have been entertained with animated scripts, cartoons, movies, and/or commercials. However, this type of animation was produced in two-dimensions. The popularity has increased in the past 10 years due to the advancements in technology related to computers and graphics software. Today's animation is created in three-dimensions (3-D).

The term 3-D refers to any visual presentation that attempts to recreate the illusion of depth on the screen as seen by the viewer. The basic concept involves taking two pictures with identical technical characteristics. The pictures are then viewed in such a way that each eye sees only the image taken on the same side as the eye. The viewer's visual cortex will interpret the pair of images as a single three-dimensional image. This process was used in early film making dating as far back as 1915. Today's 3-D technology still uses the basic concept, but the illusion is produced using computer images instead of photographs.

New applications for animation usage appear each day. A generation of people has grown up with animation software. As the technology becomes more and more accessible, adults, as well as children, are being exposed to animation. A wide range of applications is currently in place.

Business

The business segment of the digital graphics industry is one of the most rapidly growing areas. All types of industries, from catalog companies to healthcare providers, are utilizing multimedia products ranging from business-to-business and business-to-consumer marketing tools, to the design of corporate intranets (Atchley, 2003). Governments, non-profits, and other organizations are also utilizing interactive digital graphics products. Many companies that started in other segments of the digital graphics industry are gravitating into business applications (Atchley, 2003). The growth rate of the number of corporate intranets is estimated to be exceeding the growth rate of the Internet (Atchley, 2003). An intranet can be thought of as a smaller, private version of the Internet. While anyone with a computer and modem can access the Internet, only company employees and other authorized users can access an intranet. Also, most corporate intranets utilize high-speed telecommunications lines to provide easy, fast, and secure access to their information. Communications between and within departments and employees improve when a well-designed intranet is installed.

The trend in corporate downsizing has actually led to an increased demand for business multimedia products that provide the ability to communicate and train employees with less staff (Atchley, 2003). One example of increased productivity is in the area of sales support. The ability to get critical information to a geographically diverse sales force at the precise moment information is needed, rather than waiting for a site visit or a phone call from a product manager, has allowed substantial savings in personnel costs for companies that are utilizing this technology (Atchley, 2003).

In the area of workforce training, companies are beginning to realize the cost savings from computer-based training and distance learning versus traditional training held in a classroom setting. Interactive digital graphics is the perfect solution for providing training that employees can access at any time and place. Individual needs of employees are effectively met with the ability to customize their training. The training product can also be a useful reference tool.

The dynamics of communication between companies and their customers have changed with the use of electronic mail and customer service web sites. Many questions that would have formerly required actual contact with a customer service representative can now be satisfied by connecting to the company's web pages or searchable customer support database resources. Additionally, a corporate presence on the Web is becoming expected as part of an overall corporate communications strategy (Atchley, 2003). Electronic commerce, while still experiencing growing pains, is expected to cause significant changes in consumer and business purchasing habits. Standards are being developed in order to ensure confidence in the security of commerce over the Internet (Atchley, 2003).

Education

In recent years, the use of computer-generated slides to accompany live presentations has become increasingly common (Zongker, 2003). There is a potential for using computer graphics to increase the effectiveness of all types of presentations. Animations of 3-D computer graphics are becoming an increasingly prevalent medium for communications. There are many sources of 3-D animations, including physical simulations, scientific visualizations, and classic key-frame animations (Briceno-Pulido, 2004). The education segment of the digital graphics industry has two general areas of market focus: (a) curriculum-based products, which are sold directly to K-12 schools and (b) edutainment products, which are targeted for home use (Zongker, 2003). These edutainment products contain educational content presented in a game format (Zongker, 2003).

Initially, the early focus was on the school market. However, many companies found this market hard to penetrate because of the complicated effort involved in getting a product into schools, including resistance from teachers, who are not yet comfortable with computer use, and a lack of computer resources and budgets. As a result, many educational companies adapted and targeted their products towards the home school market (Atchley, 2003). This is slowly changing as school districts are recognizing the value of interactive learning and are adjusting their budgets and curriculums to incorporate the use of computers and technology products. In addition to having their students use interactive digital graphics products, many schools are also having students create content using multimedia tools (Atchley, 2003).

Animation has been used to improve students' comprehension of the limit concept in an experimental course of mathematics (Kidron, 2002). Younger students live in a multimedia world. Today's mediacentric youth perhaps think differently than previous generations, with implications as to the kinds of instructional strategies that will be successful in motivating them to learn and providing perceptual stimuli for recognition and recall (Kenny, 2001). Education will not be improved by technology; rather, education improves by teachers who develop creative methods and strategies for using technology in their classrooms (Beaudin, 2002). Voice recognition software with advanced 3-D graphics is aiding teachers with creative methods of instruction for visually impaired students. Virtual reality classrooms create a unique setting for education at all levels.

Interactive electronics computing enables users to manipulate text, graphics, and sound into new multiliteracy models that emphasize patterns of relationships rather than discrete entities (Search, 2003). The curriculum applications using 3-D animation are endless. Constraints that characterize this market segment include limitations that result from the unchanging nature of some educational subject matter, and consequently, parents often buy only one product for that subject. Companies whose products include those subjects that do benefit from content updates are moving to hybrids, where the bulk of the data is on CD-ROM and links to the Internet allow users to access updated information while using the program (Atchley, 2003).

Engineering

Computer technologies suggest new advances in merging words, sound, and visual images within the domain of the computer. Hyperlinking and animation allow for new kinds of textual structures and linguistic mobility (Smith & Dean, 2002). Researchers at Purdue University are creating interactive software that animators could use to make realistic cloud formations, explosions, smoke, steam, fog, and other gaseous phenomena for movies and video games (Ebert, 2003).

Meteorologists may also use the same software to create accurate representations of weather conditions (Ebert, 2003). The software has been designed using mathematical algorithms, which provides natural, intuitive controls. Thus, the animator would not have to deal with scientific details, such as pressure and density, thermal convection, the percentage of dust and ice particles and all of the things that a meteorologist would look at (Ebert, 2003). Clouds are very hard to animate because of their amorphous nature. This software will allow realistic animations (Ebert, 2003).

Parametric modeling is another type of animation being used in many manufacturing settings. Product design engineers are able to create 3-D models and test the accuracy of the design by applying animation. Movement added to the model aids in checking engineering specifications, such as tolerances, fit, and clearance for openings.

Films/Movies

The animated feature film industry is experiencing an explosion. This type of renaissance has not been seen since the glory days of Disney. One has to inquire why animation has become so popular and is pulling such large crowds to the theaters. A collection of comments from directors, producers, animators, and a film critic voice their opinions about this popularity (*Sydney Morning Herald*, 2004).

1. Tim Brooke-Hunt, producer for Illawarra Animation: Before the 1990s, most commercial animation was two-dimensional and very popular as proven by Disney. "The first 3-D computer-animated feature was *Toy Story* released in 1995. With the release of this movie, animated characters suddenly had depth. It (3-D) made the characters appear more real" (p.3a).
2. Arvil Stark, executive producer at Ambience Entertainment: When we used to have ordinary Bugs-Bunny style animation, it had to be sent to factories. Now, animation can be made by individuals. One to two people in their bedrooms are making 3-D computer animation, and they're getting onto TV and film festivals (p. 3a). The industry is growing by leaps and knows no bounds. There were only

five American animated feature films in 1996. In 2000, the count had risen to eight. This year alone, dozens more are slated for production.

3. Adam Elliot, Melbourne filmmaker: "Animations often make more money from the merchandising than from the box office" (p. 3a). Young people, having grown up with animation, are comfortable with graphics on computers, PlayStations, and Game Boys. Making the switch to cinema is an easy move. The more children watch animation, the more their parents become animation-literate as well.
4. Deane Taylor, Adelaide animation director: Producers, directors, animators and writers emphasized that a good story is paramount to the success of any film. Scripting animation for adults and kids started with the mixed live-action and 2-D animation film *Who Framed Roger Rabbit* released in 1988. Suddenly animation was cool for adults and not just babysitting. I think the next turning point came with *Toy Story*, for the 3-D aspect. They were equally aware of making it cool for adults (p. 3a).
5. Greg Smith, Director of communications and public affairs at the Sydney production house Animal Logic: "Animation's more collaborative. Because you're dealing with storyboards, it's more malleable. You can tweak and refine more and more until you're happy" (p. 3a). The creation of animation films is very different from live-action films. Organized crews make up large animation houses. A crew usually consists of animators, modelers, and environment artists. The crew answers to its director, who answers in turn to the overall director. Although a script is usually developed, animators tend to work from the storyboards. This allows for more creative input.
6. David Stratton, film critic: "Animation goes back to the beginning of cinema" (p. 3a). Animation popularity started when Disney's *Snow White and the Seven Dwarfs* was released in 1937. Animation's general appeal is due in part to the dazzling visuals. Today, some of the people come simply to see what the new technology is capable of.

Games / Gaming

The gaming community is the driving force behind the advancement of computer graphics (Allen, 2004). According to Allen (2004), more money is spent each year for the purchase of video games than is spent on attending movies. Games are a billion-dollar industry and a big part of the animation business (Maestri, 2001). The main driving force behind computer developments is based on the gaming industry. Almost every game has animation in one form or another, and most of the animation is in 3-D (Maestri, 2001). A new breed of multimedia workstations has to be designed to provide real-time support, interfaces to high-speed networks and multimedia peripherals (Janus, 1994). Janus' study in the early 1990s hinted that changes were coming to the field of computer design. He stated in his thesis that the gaming industry will require enhanced multimedia techniques. His suggestions have held strong over the past several years.

When multimedia-ready desktop computers first started becoming popular, Janus (1994) predicted that one of the largest markets for applications would be games. While this may have been the start of the industry, as we now know it, the games market has not found broad consumer appeal as expected, but rather has become established as a successful niche market. Games have served as a driving force behind many of the technological and artistic improvements that have led to the overall success of the digital graphics industry (Atchley, 2003). Presently, this industry segment is characterized by a wave of consolidation among companies (Atchley, 2003).

The top 10 titles of the games market account for the majority of the market revenues, which makes it difficult for smaller companies to compete (Atchley, 2003). Many entertainment companies have recently created interactive product divisions in order to capitalize on characters or technologies they own. The market has recognized that games, especially those geared to children, are much more successful when they feature a character that has been established in a film or television show (Atchley, 2003).

In order to compete in this market, new games require a high level of artistic and technological innovations. Firms try to hire people who love playing games, otherwise known as gamers. One of the more unique aspects of this segment of the digital graphics industry is the fact that both the target market for these products, as well as the employees who create them, are predominately male (Atchley, 2003). Efforts are being made to create games of interest to females, which may help create a new pool of gamers from which to hire (Atchley, 2003).

Gaming has even moved to a new delivery mode. Mobile gaming encompasses several categories of hardware, including cell phones (both online and voice-based), personal digital assistants, which may also have phone capabilities and mobile game platforms, such as GameBoy Advanced and the Sony Play Station Portable (Harz, 2004). Mobile gaming has been charging forward with revenues over $1.5 billion for the year of 2003. The compound growth is expected to be around 60 percent per year, with revenues of around $7.4 billion by 2007 (Harz, 2004).

The largest of the categories is by far the cell phones. Almost all new phones can play games. However, there are still several non-compatible standards that game developers have to design for, and games still have to be tweaked for individual models of phones (Harz, 2004). According to Harz (2004), this allows for a very fertile market area for apartment animators.

One of the largest gaming communities currently exists for personal computer (PC) players. There are currently 420,000 people playing Sony's personal computer game, *EverQuest*, with more than 100,000 around the world logging on simultaneously at peak time (Rauguest, 2004). *EverQuest* is just one of many animated games that require the constant attention of developers who work with a host of animators. With the introduction of the new PSP hardware component, even more jobs will be made available to animators (Rauguest, 2004).

Another new development in the gaming industry is mobile gaming called location based gaming (LBG). This allows the game device to move around the city instead of moving a mouse around a desktop. The games work by overlaying a gaming grid over the map of the city and then tracking the players by using either the built-in graphical positioning system (GPS) function in the phones or the location capability of the phone network (Harz, 2004). According to Harz (2004), no estimates exist for the projected growth of LBGs. However, LBGs will likely become a staple of gaming. It is also likely that businesses will step in and offer rewards for gameplay in their neighborhoods, such as visiting certain stores or restaurants or being able to answer questions about historical sites (Harz, 2004).

Video games have morphed from being primitive toys for geeks and kids into a major form of entertainment. Sale of video game hardware, software and gear jumped 2.4 percent to a record $9.4 billion in 2002 (Krantz, 2002). Companies like Sony, Electronic Arts, and Barnes & Noble have jumped on board. While tech giants, such as Sun Microsystems, Hewlett-Packard, and Intel, can't seem to get rid of people fast enough, video game makers are hiring. Graduates often land starting salaries of $50,000 to $60,000 a year, but can quickly earn $100,000 or more if they're part of a team that makes a best-selling title (Krantz, 2002).

Geographic Information Systems

For years, viewing geographical information systems (GIS) data in 3-D has been a valuable way to aid users in visualization of complex datasets. However, the 3-D application only recently included animation. GIS is a rapidly growing field that is strongly dependent on animation, yet most graphics professional are not aware of it (Harz, 2004). GIS will eventually create hundreds of companies and thousands of jobs, and change many of the ways in which we look at our world, including education, design, architecture and homeland security defense (Harz, 2004). GIS is an area in the 3-D industry that is ready to explode.

According to Christopher Harz (2004), GIS has long been a relatively low-tech profession involved with associating representations of places on earth (on maps, models, globes or digital databases) with information about those places, such as plans for construction sites, concentrations of certain types of cars in particular cities, or measurement of pollution. What has brought GIS into the forefront is the recent convergence of several new phenomena, including the availability of satellite photos, the New Internet, cheap global positioning system (GPS) chips, 3-D animation techniques and display, and wideband wireless (Harz, 2004). Through the integration of GIS technology with 3-D / animation software, a more effective presentation can be prepared (Dickerson & Greenwell, 2004). A 3-D display simulates spatial reality that allows the viewer to more quickly recognize and understand the topography (Daxikear & Chernin, 2004).

The use of animation with 3-D GIS is being used in different types of presentations. Watershed management programs seek to prevent and control pollution that may have a detrimental effect on human health and/or the environment. Three-D GIS can be used to create real world models of a watershed that enable the public to understand the complex interactions within the watershed (Daxikear & Chernin, 2004). Three-D GIS is also growing rapidly in other fields, such as hazardous waste remediation / investigation projects, environmental / traffic planning, and impact analysis (Harz, 2004). Movie maps, the animated equivalent of a paper map with cartographic elements, such as titles, legends, and logos, have recently been used to show hazards associated with Lake Michigan shoreline erosion, coastal flooding, and low lake levels (Daxikear & Chernin, 2004). Movie maps are used to communicate key findings to the study team and the general public. This aids with understanding the situations for non-technical audiences (Daxikear & Chernin, 2004).

Emergency response GIS application is another growing field tied to animation (Higher Education Solutions Group of ESRI, 2004). In 2004, wildfires raged all over Southern California. Emergency responders, operations commanders, government officials, and others used GIS software for daily briefings and strategy sessions (Higher Education Solutions Group of ESRI, 2004). The use of 3-D analysis and animated fly-through provided several benefits for the emergency workers (Higher Education Solutions Group of ESRI, 2004).

Three-D GIS is fast becoming an important tool for the industry. While 3-D analysis is not yet commonplace in decision-making, the ability to use 3-D GIS to render complex contour maps understandable for the layperson, makes it an invaluable tool (Daxikar & Chernin, 2004). Currently, 3-D GIS with the addition of animation is a work in progress. The establishment and visualization of large, reality-based 3-D landscape and city models has received significant attention over the last few years, both in the scientific and the commercial communities (Nebiker, 2004). As geospatial technology matures and becomes more pervasive, there will be a need to define the profession and provide the best training and education (Higher Education Solutions Group of ESRI, 2004).

Law / Forensics

In the make-believe world portrayed by television programs, such as CSI, Crime Scene Investigation, the role of forensic experts is depicted as exciting and adventurous. In real life, of course, this is several degrees away from the truth. In terms of analysis, forensic science can be divided into four traditional areas: (a) toxicology, (b) drug science, (c) DNA and blood spatter analysis, and (d) the (chemical) analysis of marks on the body (Pearson, 2003). The latest techniques in all of the four traditional areas are conducted using the fast-moving arena of computer animation. Forensic animation is the computerized illustration of events recounted by courtroom testimony. It is the newest in a chain to technologies, from lie-detector tests to handwriting analysis and DNA sampling, which is transforming the world of litigation (Ward, 2002). This type of animation has spawned a thriving industry and provided animation jobs around the globe (Ward, 2002).

The animation field has grown exponentially and the use of forensic animation is quickly becoming a common occurrence in the courtrooms of the 21st century (Gold, 2004). As early as 1985, computer animation made its way into the courtroom with the landmark case of Delta flight 191. A 45-minute computer generated presentation was created to explain the intricacies of the evidence and thus began forensic animation, a new field of collaboration between art and science (Gold, 2004).

Forensic animation is an art that, in the past decade, has expanded tremendously in the world of civil suits, as well as in the world of law enforcement and criminal cases (Mertnes, 2004). Animations are an illustration of an expert's testimony, says Sgt. Francisco Carrera of the Illinois Police (Mertnes, 2004). Within the next few years, the computer savvy generation will enter the workforce. It is this group of young people who will make a difference in the forensic animation world. The field of animation will continue to grow, as well as the educational requirements for this high-tech field. Although forensic animation in the courtroom remains somewhat controversial, the application is definitely here to stay (Marks, 2001).

Medical

Medical graphics is not a new concept by any means. Depictions of the human body through art have existed since caveman's time. However, the quality and depth of medical art has changed dramatically since that time. Medical 3-D animation is now very detailed, accurate, and allows illustrations that are instrumental in understanding scientific and medical processes (Tec Bytes, 2004). Three-D is allowing patients to become more involved and to be better informed about an operation. Animation gives patients more knowledge about their procedure and a good understanding about what is going on during surgery. The patients also see the effects of what could happen in their bodies during and after surgery. In most cases, the animation is done in a non-gruesome way without showing the "blood and guts" situations.

Medical animations and illustrations are no longer restricted to education in the scientific sector. Many other areas are using medical animations, such as law firms, research agencies, journals, magazines, newspapers, television programs, and museums (Tec Bytes, 2004). These fields may not be directly related to the healthcare profession, but the growing demand for the production of high quality medical animation and illustration is phenomenal (Tec Bytes, 2004).

Models have been used to teach human anatomy for over 1000 years (Vernon & Peckham, 2002). Today, visually rich and often interactive 3-D computer-generated images are being used to teach anatomy. A revolution is under way in classrooms and dorm rooms at Hopkins Medical University. Students are sitting at their computers and learning medicine by watching videotaped lectures that contain graphics, full-length animation, and virtual laboratories (Gilbert, 2004). The creation of virtual medical museums, comprised of 3-D models derived from data scanned from gross specimens, is a growing trend (Vernon & Peckham, 2002). As early as 1989, the *Visible Human Project*® began an ambitious process to create a digital atlas of the human anatomy (National Library of Medicine, 2005). According to the National Library of Medicine (2005), the project was highly successful and is used daily in many different arenas.

Robotics and virtual reality techniques used in the simulation of surgical procedures, which are similar to those used in the simulation in flight training, can allow a young surgeon in training to interact with an imaginary human body (Lorenzo & Gaspart, 2003). Because of this type of training, hundreds of robots have invaded operating rooms across the globe. Surgeons are inviting these robots to be the newest members of their teams. The machines are ushering in an era of surgical precision and results unmatched by the human hand (Pearson, 2003).

Administering the Research Test

The primary sample population in this study consisted of subjects who were directed to an online survey after receiving an introduction email. The subjects were directed to a hard-coded link connecting them to a cover letter. After review of the cover letter, the contacts participated in the survey. The participants receiving the introduction email were EAST facilitators from the defined mid-South region.

Additional information was collected using individual and group interviews. A focus group aided in the development of the survey instrument. One of the defining elements of qualitative inquiry is the role of the researcher (Patton, 1990). Patton (1990) stated that the investigator becomes a part of the study while acting as the research instrument. The researcher organized data obtained from the focus group. These data examined the gap occurring in the visual graphics animation area. The survey instrument was developed by the focus group from collected data.

Results and Analysis of Data

The survey population came from the EAST facilitators in the area defined as the mid-South. Table 1 lists the mid-South region sites. Only high school programs are listed in this information. According to the *Animation Magazine* (School Guide, 2004), there are several colleges offering animation related degrees located on the West coast of the United State of America. For this reason, the states of California and Hawaii were not included in this study. The nature of the instrument did not allow the researcher to know the location of the respondents. A population of 124 facilitators (N=124) responded to the survey. The 124 respondents make up 90.5 percent of the high school facilitators located in the mid-South region.

Mid-South Region (High School Programs only)	Frequency	Percent
Alabama	1	0.7
Arkansas	118	86.1
Illinois	15	10.9
Louisiana	2	1.5
Mississippi	1	0.7
Total	137	100.0

Table 1. Location of EAST Initiative Sites by Mid-South Region

The survey questions list specific fields of animation for the interest of students. The facilitators agree their students show an interest in the animation fields of (a) advertisement, (b) video gaming, (c) movie industry, (d) video editing or production, and (e) crime scene investigations. One-way ANOVA was calculated comparing the programs showing a strong interest in video gaming with the other programs. Table 2 displays the results of the ANOVA.

Source	df	SS	MS	F	R^2	p-value
Between Groups	3	20.63	6.877	12.81		<.005
Within Groups	30	16.12	.537			
Total	33	36.75				

Note: N = 124
* = Significant at .005 level

Table 2. ANOVA Summary Table for Investigating the Interest in Video Gaming and Other Animation Fields

A variety of descriptive statistics were calculated to determine if there was interest in a four-year degree. The EAST facilitators (29.0 percent) report that past EAST graduates had or were attending some type of college upon high school graduation. The EAST facilitators report that the current EAST students (95.2 percent or 118 schools) have an interest in pursuing a four-year degree. Of this reporting group, 61.3 percent (76 schools) had students interested in a Visual Graphics four-year degree. The facilitators (41.2 percent) report that their students would be willing to travel as far as it takes to obtain the quality degree. The remaining facilitators (58.8 percent) report that their students would travel up to 400 miles to obtain a quality degree in Visual Graphics Animation.

The EAST facilitators (61.3 percent or 76 schools) report that the students have an average ACT score that ranges from 21 to 25. Only 2.9 percent of the reporting schools list the average ACT scores range higher than 30. The reporting schools report that their program population range is less than 10 to 25 students. The facilitators agree to encourage the students to attend a four-year program in Visual Graphics Animation. The facilitators also show an interest in taking courses in animation. Skills acquired by the EAST students will transfer to a four-year program. The facilitators agree that the availability of scholarships will directly impact the enrollment in the program.

Conclusions

The acquisition of animation can offer diverse occupational opportunities. There are many jobs associated with the creation of visual graphics. The mid-South region shows strong interest in animation and related occupations. There are current and past EAST high school students interested in perusing a four-year degree in Visual Graphics Animation. Business and industry in the mid-South regions are expanding to include animation activities, thus opening the job market for graduates from a four-year Visual Graphics Animation degree. A quality four-year degree will attract students from the mid-South region. Facilitators and students show strong interest in the offerings of animation courses. The recent growth of 3D graphics has encouraged students to seek degrees in animation related programs.

Results from the Study

Since the completion of the initial study conducted between the years of 2005 and 2007, additional research has been completed. The EAST Initiative school population has changed slightly. There are now six states with EAST programs of study. These states include Arkansas, California, Oklahoma, Iowa, Louisiana, and Pennsylvania (EAST, 2010). Also since the original study's completion date, electronic sales (including video games, high-tech toys, animation applications, etc.) have far exceeded all expectations showing that animation is here to stay and grow. For example, Modern Warfare 3 (2011) released early in November of this year has become the biggest entertainment launch of all time. According to Kyle Orland (2011), "Modern Warfare 3" sold 9 million copies in the U.S. in November across the Xbox 360, PS3, Wii and PC. That's about 7 percent better than the first-month sales for last year's "Call of Duty: Black Ops," which has gone on to sell over 23 million copies worldwide.

The College of Applied Science and Technology located on the campus of the University of Arkansas – Fort Smith has developed and implemented a four-year completer degree in Animation Technology. The program was officially approved by the Arkansas Department of Higher Education in June 2010. An assertive effort toward marketing the new degree to the current and past graduates of the EAST Initiative is under way. Additional research results will be reported at a later date.

References

Allen, L. (2004). The action of gaming. *Cadence 42*(14). 28-36.

Arkansas Department of Workforce Education. (2005). *Data on WAGE*. Retrieved March 28, 2005 from http://dwe.arkansas.gov/AdultEd/WAGE.html

Atchley, W. (2003). Digital design: Animation overview for a four-year degree. Research paper presented for a final project at the University of Arkansas – Fort Smith campus.

Beaudin, L. (2002). Authenticity and technology integration: A structure to aid teachers dealing with changing computer technology. *International Journal of Learning,* 9. Retrieved July 27, 2004 from http://lc2002.publisher-site.com/ProductShop/view_product/html

Briceno-Pulido, H. (2004*). Geometry videos: A new representation for three-dimensional animations*. Ph.D. Dissertation, Massachusetts Institute of Technology.

Daxikar, A., & Chernin, P. (2004). Use of 3-D GIS as a visualization tool for watershed management. Retrieved September 30, 2004 from http://gis.esri.com.library/userconf/proc01/professional/papers.htm

Dickerson, S., & Greenwell, L. (2004). The integration of GIS with 3D / Animation software for presentations to local government. Retrieved September 21, 2004 from http://gis.esri.com/library/userconf/proc00/professional

Ebert, D. (2003). *Purdue software promises better animation for movies and games.* Purdue News Service. Retrieved March 15, 2005 from http://news.uns.purdue.edu/html14ever/030716.Ebert.clouds.html

Environmental and Spatial Technologies. (2005). *EAST initiative*. Retrieved March 10, 2005 from http://www.eastproject.org

Environmental and Spatial Technologies. (2010). *EAST initiative*. Retrieved September 10, 2010 from http://www.eastproject.org

Gibbs, H. J. (2005). Playing a role in historic preservation. *Techniques: Connecting Education and Careers 80*(4).

Gilbert, P. (2004). Enter: The living medical textbook. Retrieved March 14, 2005 from http://www.hopkinsmedicine.org/hmn/S03/feature1.cfm

Gold, S. (2004). Forensic animation – its origins, creation, limitations and future. *Shadow and Light Produtions*. Retrieved March 15, 2005 from http://www.shadowand light.com/4NsicArticle.html

Harz, C. (2004). Growing possibilities: Mobile gaming 2004. *Animation World Magazine*. Retrieved February 1, 2005 from http://mag.awn.com/?articles_no=2051

Higher Education Solutions Group of ESRI. (2004). *Curriculum development and the workforce*. Redlands, CA: GIS Educator.

Janus, I. (1994). *Identifying requirements for support of distributed multimedia applications.* Master Thesis. University of Houston.

Kenny, R. (2001). *Annual proceedings of selected research and development*. Paper presented at the National Convention of the Association for Educational Communications and Technology, Atlanta, GA.

Kidron, I. (2002). The role of animation in teaching the limit concept. *International Journal of Computer Algebra in Mathematics Education, 9*(3), 205-227.

Krantz, M. (2002). Video game college is "boot camp" for designers. USA Today. Retrieved January 16, 2005 from http://www.usatoday.com/money/media/2002-12-03video_x.htm

Lorenzo, N., & Gaspari, A. (2003). The virtual patient – a new option for surgical education. *Business Briefing: Global surgery*. Retrieved March 15, 2005 from http://www.bbriefings.com

Maestri, G. (2001). Animation for games. *New Riders*. Retrieved January 14, 2005 from http://www.informit.com/articles/article.asp?p=22801&seqNum=1

Marks, S. (2001). Body of evidence. *Computer Graphics World.* Retrieved February 2, 2005 from http://cgw.articles.printthis.clickablility.com

Mertens, J. (2003). *Animation takes a forensic twist*. Illinois State Police Website. Retrieved February 2, 2005 from http://www.isp.state.il.us/media/let0903fda.cfm

National Library of Medicine. (2005). Marching through the visible man. Retrieved February 16, 2005 from http://www.crd.ge.com

Nebiker, S. (2004). Support for visualization and animation in a scalable 3-D GIS environment – motivation, concepts and implementation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 36*(5). Retrieved September 24, 2004 from http://www.photogrammetry.ethz.ch

Orland, K. (2011). Modern warfare 3 wins Nov with 9M U.S. retail sales.. *MSNBS News Report*. Retrieved December 12, 2011 from http://ingame.msnbc.msn.com/_news/2011/12/12/9395054-modern-warfare-3-wins-nov-with-9m-us-retail-sales

Patton, M. Q. (1990). *Qualitative evaluation and research methods.* Newbury Park. CA: Sage Publications.

Pearson, H. (2003). Robots invade the operating room. *MSNBS News Report*. Retrieved February 17, 2005 from hpttp://msnbc.msn.com/id/3403901/print/1/displaymode/1098

Pearson, S. (2003). Forensic science: The facts behind the fiction. *The Biomedical Scientist*. Retrieved March 14, 2005 from http://www.cs.nott.ac.uk/~dzs/news/mefertoto.pdf

Rauguest, K. (2004). Online functionality boosts console gaming industry. *Animation World Magazine*. Retrieved February 1, 2005 from http://mag.awn.com/?article_no=2038

School Guide. (2004). School guide for animation programs in the United States. *Animation Magazine*, *16*(1), pages A2-A16.

Search, P. (2003). The metaphysical dynamics of interactive electronic design. *Visible Language, 37*(2), 145-164.

Smith, H., & Dean, R. (2002). The egg the cart the horse the chicken: Cyberwriting, sound, intermedia. *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning, 4*(1). Retrieved July 26, 2004 from http://imej.wfu.edu/articles/index.asp

Sydney Morning Herald. (2004). *Why 3-D animation rules the day*. Retrieved October 12, 2004 from http://www.smh.com.au/articles/2004/06/16/1087244972042.html

Tech-Bytes Technology. 2004. *Medical animation and medical illustrations outsourcing guide.* Retrieved February 16, 2005 from www.onlypunjab.com/tech/fullstory-newsID-250.html

Vernon, T., & Peckham, D. (2002). The benefits of 3D modeling and animation in medical teaching. *Journal of Audiovisual Media in Medicine*, *25*(4), 142-148.

Walt Disney Studios. (2004). *History of the Walt Disney studios*. Retrieved July 13, 2004 from http:// Disney.go.com/StudioOperations/Welcome/history.html

Ward, J. (2002). Crime seen. *Architecture Magazine*, *10*(05). Retrieved March 18, 2005 from http://www.wired.com/wired.archive/10.05/forensics.html

Zehr, D. (2004). State entrepreneurs ill-funded. *Arkansas Democrat-Gazette*, April 14, 2004.

Zongker, D. (2003). *Creating animation for presentations*. Ph.D. Dissertation, University of Washington

Examining Active Learning: Review and Current Thinking

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Abstract

Higher education has in the past heavy relied on the lecture method of teaching. Beginning in the 1970's, techniques for greater student involvement, active learning, began to be suggested and researched as a means of improving students' mastery and retention of content as well as a way to improve on the development of problem solving strategies. Since that time, numerous strategies have been investigated and found to be effective means to improve students' achievement. This paper examines the concept of active learning as well as some strategies that can be used in classes to employ it. Along with a short summary of activities that can be used to improve lectures, it also looks at several proven collaborative methods that involve students working in teams.

Introduction

Since the 1970's, individuals have looked at ways to improve student learning through a concept known as active learning. It was understood that learning requires an individual to be active and engaged in the construction of one's own mental models, and instruction needed to be moved from a teacher centric model to a student centric model, where students become part of the means of their own instruction. A number of different strategies to accomplish this have been suggested and researched since that time. Likewise, research on the effects of active learning on student achievement has demonstrated its effectiveness (Michael, 2006).

Michael (2006) provides the following definition of active learning: "The process of having students engage in some activity that forces them to reflect upon ideas and how they are using those ideas. Requiring students to regularly assess their own degree of understanding and skill at handling concepts or problems in a particular discipline. The attainment of knowledge by participating or contributing. The process of keeping students mentally, and often physically, active in their learning through activities that involve them in gathering information, thinking, and problem solving" (p. 160).

According to Bonwell and Eison (1991), literature on active learning generally shows that active learning techniques include the following characteristics:

- Students are involved in more than listening.
- Less emphasis is placed on transmitting information and more on developing students' skills.
- Students are involved in higher-order thinking (analysis, synthesis, evaluation).
- Students are engaged in activities (e.g. reading, discussing, writing).
- Greater emphasis is placed on students' exploration of their own attitudes and values. (p. 2)

Meyers and Jones (1993) describe a structure for active learning that shows how the elements of active learning create the building blocks of active learning strategies (p. 20).

Elements
talking and listening
writing
reading
reflecting
↓
Learning Strategies
small groups   cooperative work   case studies   outside speakers
discussion teaching   problem solving   journal writing
↑
Teaching Resources
readings   homework assignments   outside speakers
teaching technology   prepared educational materials   commercial and educational television

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Figure 1: Structure of active learning.

This chart provides a good visual representation of how the parts of active learning fit together and also provides a list of some of the techniques that are discussed by writers on active learning. Not all of them are appropriate to every field of study, but there are some strategies that can be employed in every field. Teachers must decide on the appropriate active learning techniques that work for their specific continuum of learning for their subject area (Meyers and Jones, 1993).

The teaching strategies in active learning vary from low to high risk. Even low risk strategies, according to the literature, provide a great deal of benefit over the "traditional" lecture that is the mainstay of many college classrooms (Bromwell & Eison, 1993).

Issues with Traditional Lectures

Why don't simple lectures work effectively as teaching tools? Research has demonstrated that only 62 percent of lecture content is remembered by students immediately following a typical 50-minute lecture. This drops to 45 percent after three to four days, and only 24 percent after 8 weeks. The primary issue with lectures as a teaching method is that they lead students to assume a passive role and become non-thinking receivers in the classroom (McKeachie, 1999).

Memory researchers have shown that information processed to a 'deep' level will be better remembered than information processed only to a 'shallow' level. Craik and Lockhart's levels-of-processing theory predicts that information processed using a more deep and thorough analysis of meaning is remembered better than information processed in a shallow and superficial analysis of structural features. Elaboration of the material, which involves interpreting information, connecting it with other information, and mulling over it, is an important aspect of deeper encoding of information (Cherney, 2008). Lectures do not reach this level of information processing. Likewise, according to Michael (2006), learning facts and learning to do something are two different processes. Our field, like many others, must teach both. If you expect students to be able to solve problems, you must provide them with opportunities to practice the application of knowledge, practice the skills they need, and provide them with feedback about their performance.

Researchers' insight into the mechanisms underlying retrieval from long-term memory is that retrieval is cue dependent, that is, it is stimulated by hints and clues. Many instances of forgetting occur, not because the information sought has been lost from memory, but because the cues used to probe memory are ineffective. Context provides very powerful retrieval cues. Memories are stronger and more detailed when they are experienced and are rich in context cues.

An Example of an Active Learning Model

In a book by Hazzan, Lapidot, & Ragonis (2011), written for the training of computer science educators, they outline an active learning model. They created a model that follows four essential steps. This is just one example of how active learning can be structured for optimum student success. Such methods can be adapted to different course types and strategies.

1. **First stage: Trigger**— Following a constructivist perspective, the objective and topic is introduced. The objective here is to introduce a topic with a worthwhile assignment in a nontraditional fashion. The challenge is to provide an active-learning-based trigger, an open-end activity with which students are not familiar. The trigger should enhance and foster meaningful learning and should raise a wide array of questions, dilemmas, attitudes, and perceptions. The trigger should be realistically complex and relevant. Depending on the trigger's objective, the activity can be worked on individually, in pairs, or in small groups.

2. **Second stage**: **Assignment** — At this stage, the students work on the assignments, which can vary in time depending on the type of activity assigned.
3. **Third stage**: **Discussion** — After the activity is completed, in either groups or as individuals, the class is brought back together to discuss the trigger, product produced, and the broader concepts being taught. Thoughts, opinions, and concepts that originated during the activity are discussed during this time. Here the instructor can emphasize concepts, unique solutions, and other offshoots of the activity. Students are encouraged to speak out and voice their ideas and opinions.
4. **Fourth stage**: **Summary** — The last stage allows the instructor to summarize what was being learned, put the concepts into a framework, and relate items to each other.

Cooperative and Collaborative Learning Strategies

One of the strategies for incorporating active learning into courses is the use of cooperative learning. In cooperative/collaborative learning strategies, students, in teams of two or more, are assigned a common task or problem. Do they employ cooperative or collaborative active learning strategies? That may be for the instructor to decide. Though these two approaches may be applied to the same learning techniques, there is one considerable difference: teacher prescribed or student structured, respectively (Abrami et al. 1995; McWhaw, Schnackenberg, Sclater, and Abrami, 2003). Either way, students work to achieve definitive results (Panitz, 1997; McWhaw et al. 2003, Felder & Brent, 2007).

Johnson, Johnson, and Stanne (2000) describe a continuum for cooperative learning methodology from very concrete to conceptual. Teachers may impose well-defined techniques that are very direct and straightforward. On the other hand, teachers can use theoretical frameworks to restructure current lessons and activities into cooperative learning activities. The flexibility in this type of cooperative/collaborative learning motivates and empowers students. They are responsible for and take ownership in their learning.

Scales (1995) reports two learning goals for cooperative/collaborative teaching strategies. One is to increase student learning, and the second is to develop student social skills. The development of interpersonal skills, according to Smith & McGregor (1992), is as important as the learning itself. Cooperative and collaborative learning require a collective, intellectual team effort, where students seek comprehension, significance, and results as they explore and apply course content (Smith & McGregor). Practical techniques stimulate learning and higher level thinking (Cohen, 1994).

Specifically, in engineering education, Johnson, and Johnson's model of cooperative learning (broadened by Karl Smith) is "the one most commonly used" (Arizona Board of Regents, 2002, ¶5). Johnson, Johnson, and Smith (1998) signify five elements as "critical to actual cooperation" (p. 30).

- Positive interdependence
- Individual accountability
- Promotive interaction
- Collaborative skills
- Group processing

These components are essential in fostering the success of cooperative and collaborative teams. Engineering Education generally practices three particular learning techniques: Jigsaw, Think Pair Share, and Think Aloud.

Jigsaw

Forty years after it was first used, the Jigsaw strategy remains one of the most common and effective techniques of cooperative learning. In a meta-analysis of 164 studies, Johnson, et al. (2000) found that Jigsaw (among others) had a significant positive impact on student achievement. Teachers, likewise, agree it is relatively simple to use. First, Jigsaw groups of between five and six students are established with one student as the leader. Any given lesson is divided into five to six segments, with one portion assigned to each student in the group. That student then becomes the "expert" for their appointed part. Once students are familiar with their part, all the individuals with the same topic from each group form a new collaborative group and rehearse the material. As the teacher monitors, each "expert" then returns to their original group and presents the material. Lastly, students are quizzed on the topics for that lesson.

Think Pair Share

A low-risk metacognitive cooperative strategy, Lyman (1981) introduced the Think Pair Share technique in his paper, *The Responsive Classroom Discussion*. When an instructor poses a question, students consider their answer (think). After a predetermined amount of time, partners briefly discuss their answers (pair). Lastly, students take part in whole group or team discourse (share). "Think Pair Share routine promotes understanding through active reasoning and explanation. …[it] encourages students to understand multiple perspectives" (Harvard Project Zero, n.d., ¶1).

Think Aloud

Very similar to Think Pair Share but not a collaborate technique, Think Aloud is also a metacognitive strategy, developed by Afflerbach and Johnston (1984), where students actually think out loud while reading and solving problems. "Talking aloud while working out a problem…students hear how they think" (Harmin, 2006, p. 184). Monitoring their own comprehension, the learner uses a set of guiding questions prepared for a specific assignment. Guiding questions may stimulate thinking processes. For example, while working on a project, undergraduate engineering graphics students may think

- What do I already know?
- What do I expect to learn?
- How will I gather information?
- How will I recall relevant information?

Students' use of this technique allows them to develop metacognitive awareness while solving problems.

Conclusions

Active learning is not new, but as a discipline, we should be looking at all the ways we can incorporate these techniques into our teaching. The variety of methods to improve student learning allow instructors to select an active learning strategy that works for them, from low-risk adaptations of lectures to collaborative strategies that move the learning experience from teacher centered to student centered. This paper only discusses a few established techniques, but there are techniques that will fit any class situation and can impact students, not only in the content they learn, but also in the skills they develop, both social and technical.

References

Abrami, P.C., Chamber, B., Poulsen, C., De Simone, C., d'Appolonia, S. & Howden, J. (1995). *Classroom Connections Understanding Cooperative Learning*, Toronto: Harcourt Brace.

Afflerbach, P., & Johnston, P. (1984). On the use of verbal reports in reading research. *Journal of Reading Behavior, 16*(4), 307-322.

Arizona Board of Regents. (2002). *Active/cooperative learning: Best practices in engineering education*. Retrieved from http://clte.asu.edu/active/mainde.htm

Bonwell, C. & Eison, J. (1991). *Active learning: creating excitement in the classroom. Ashe-Eric Higher Education Report No. 1.* Washington, D.C.: The George Washington University, Schools of Education and Human Development.

Cherney, I.D. (2008). The effects of active learning on students; memories for course content, Active. *Learning in Higher Education, 9*(2), 152–171.

Cohen, E. (1994). Restructuring the classroom: Conditions for productive groups. *Review of Educational Research, 64*, 1-35.

Felder, R.M. & Brent, R. (2007). Cooperative learning. A. A. Mavrouk (Ed). *Active Learning: Models for the Analytical Science, ACS Symposium Series 970*, 34-53.

Gedeon, R. (1997). Enhancing a large lecture with active learning. *Research Strategies, 15*(4), 331-309.

Gibbs, G., Habeshaw, S. & Habershaw, T. (1992). *Fifty three interesting things to do in your lectures*.. Exeter, UK: BPCC Wheatons Ltd.

Gilles, R.M. & Ashman, A.F. (2003). An historical review of the use of groups to promote socialization and learning. *Co-operative Learning: The Social and Intellectural Outcomes of Learning in Groups.* R.M. Gilles and A.F. Ashman (Eds.). London: RoutledgeFalmer.

Harmin, M. & Toth, M. (2006). *Inspiring Active Learning: A Complete Handbook for Today's Teachers, Expanded 2nd Edition.* Alexandra, VA: Association for Supervision and Curriculum Development.

Harvard Project Zero. (n.d.) *Visible Thinking. Think Pair Share.* Retrieved from http://pzweb.harvard.edu/vt/VisibleThinking_html_files/03_ThinkingRoutines/03d_UnderstandingRoutines/ThinkPairShare/ThinkPairShare_Routine.html#

Hazzan, O., Lapidot, T. & Ragonis, N. (2011). *Teaching Computer Science: An activity-based approach*, London: Springer-Verlag.

Johnson, D.W., Johnson, R.T. & Karl A. Smith, K.A. (1998 July/August). Cooperative learning returns to college: What evidence is there that it works? *Change*, *30* (4), 26-35.

Lyman, F. T. (1981). The responsive classroom discussion: The inclusion of all students. In A. Anderson (Ed.), *Mainstreaming Digest*, 109-113. College Park: University of Maryland Press.

McKeachie, W. J. (1999). *Teaching tips: Strategies, research, and theory for college and university teachers.* Boston: Houghton Mifflin.

McWhaw, K., Schnackenberg, H., Sclater, J. and Abrami, P.C. (2003). From co-operation to collaboration: Helping student become collaborative learners. *Co-operative Learning: The Social and Intellectural Outcomes of Learning in Groups.* R.M. Gilles and A.F. Ashman (Eds.). London: RoutledgeFalmer.

Meyers, C. and Jones, T.B. (1993). *Promoting active learning.* San Francisco, CA: Jossey-Bass.

Michael, J. (2006). Where's the evidence that active learning works? *The America Physiological Society, 30,* 159-167.

Panitz, T. (1997). Collaborative versus cooperative learning: Comparing the two definitions helps understand the nature of interactive learning. *Cooperative Learning and College Teaching, 8*(2), 5-7.

Scales, A.Y. (1995). Teaching shouldn't be what it used to be: Active learning techniques in the classroom. Proceedings from the *50th Engineering Design Graphics Division Midyear Meeting, November, 1995*.

Smith, B.L. & McGregor, J.T. (1992). What is collaborative learning? *National Center on Postsecondary Teaching, Learning, and Assessment at Pennsylvania State University*.

Graphics Education Needed for Upper Division Courses in Mechanical Engineering Design

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Abstract

Engineering graphics are taught in the first year of the engineering program at Andrews University. This paper shows that students in the mechanical engineering program continue to use this skill in their upper division classes as well as in their extra-curricular activities such as SAE student chapter. In the manufacturing process course, the engineering students are tasked to design and subsequently produce a casted product as part of their project. This project requires students to produce a 3-D pattern for initial evaluation. To produce this 3-D pattern, students will need to convert the graphic files into a format that can be read by the 3-D printer. After evaluation of the 3-D pattern, and approval from the instructor, students will go back to the 'drawing board' to design a two-piece mold and subsequently produce a 3-D mold to receive the molten metal necessary to form the casting. This paper will also review courses such as Machine Design and Finite Element Methods taught at Andrews University that require students to have proficiency in the use of a CAD graphic software, as they are required to produce drawings of machine elements either for assembly (Machine Design) or for analysis (Finite element Analysis). Students participating in the Annual SAE Student Competition such as Mini Baja Competitions need to show their designs or modifications. These are usually done using one of the CAD graphic software.

Introduction

Engineers and scientists nowadays can create complex designs using sophisticated analysis techniques such as Computer-Aided-Design (CAD), Finite Element Methods (FEM), solid modeling, simulations, dynamic animation, database tools, and general data visualization capabilities. Michael B. McGrath, et. al., (1991) credited this to the arrival of the computer age and the demand by the industry to be competitive. Most of these techniques require the use of engineering graphics to accomplish the task comfortably. Engineering graphics has been in both the technology and engineering education with the graphics being employed both as the final outcome and intermediate stage for numerous technological design activities (Wiebe, E. N., et. al., 2001). Thanks to the knowledge and skill in the use of engineering graphics, engineers can use it to communicate ideas of components as to its shape, size, dimensional tolerance as well as layout, among many other things.

Project work is often used in the engineering program to allow students to integrate certain areas of their undergraduate training or to direct them to apply their knowledge to solve a problem. As mentioned by Nathan Scott, et. al., (2003), these projects will have varying complexity, but all will relate in some way to the fundamental theories and techniques of their discipline. Students are more likely to retain the knowledge gained by this project-based learning more readily than through traditional textbooks.

Engineering graphics has a role in most of these projects as the student needs to be able to model objects or their designs in 2-D or 3-D space and have it printed for discussion among team members.

At Andrews University Department of Engineering and Computer Science, the authors use group or individual projects as part of the learning processes in the upper division mechanical engineering program courses. In all these projects, students are assumed to have some proficiency in the use of engineering graphics software.

Manufacturing Processes Class Project

Mechanical engineering students take a manufacturing processes course as part of their major program requirements. One of the topics taught in this course is the subject of casting and casting processes. After students are taught about the robust design requirement in casting, they were tasked to design a paperweight that would be produced by a casting process. The project takes the students from visualizing their concept of the paperweight design to pouring molten metal into their 3-D printed mold to obtain the finished cast product.

The mechanical engineering students must be able to work visually and use any of the computer aided drafting (CAD) software to represent the paperweight designs in space with reasonable accuracy. After consultation with the instructor, their designs were printed using a 3-D printer and the 3-D patterns were further evaluated and mistakes identified. Students then go back to the drawing board where the mold patterns, along with the necessary gates, runners and risers for the molten metal to flow into the mold cavity, were then designed and 3-D print two halves molds were produced.

Two sample models of the graphical representation of the students' paperweight designs, a gear and a mounting stand combination set with "Andrews University Engineering" etched into the mounting stand and a half gear with Andrews University etched on the side are shown in Figure 1.

..

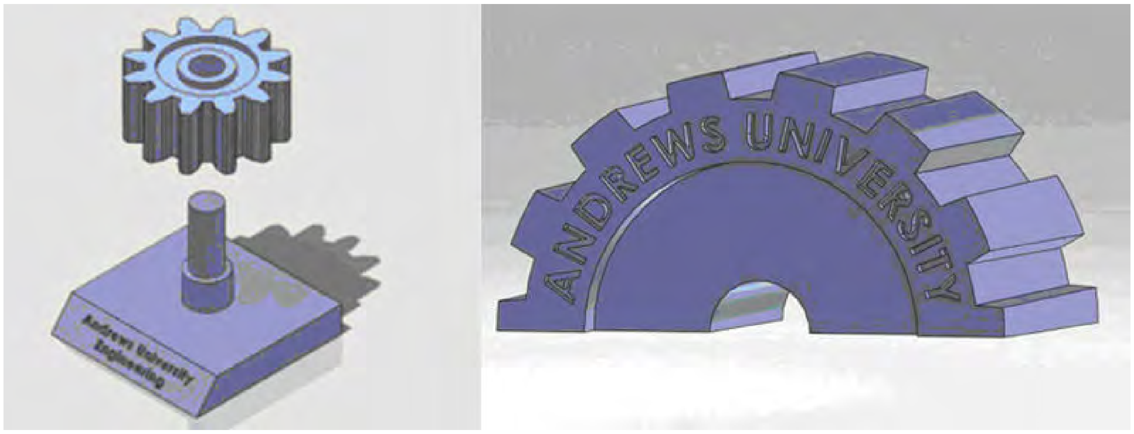

Figure 1. Student-designed paper weight models using CAD software.

The 3-D prints of their designs were shown in Figure 2. 3-D printing took about two hours followed by another couple of hours for the curing to complete. Within 4 hours, the students could see, touch and feel the 3-D paperweight models that they had designed. From the 3-D prints, the students could evaluate their designs and make the necessary corrections. In this case, it was found that the logo “Andrews University Engineering” on the mounting stand was a little too shallow/small causing the letters to smudge and this needed to be made deeper into the casting. At this point, with the 3-D print, the student and instructor would consider the best way to design the two halves mold and how the runner, riser and gate could be added to the design.

Figure 2. 3-D models of the student-designed paperweights.

CAD drawings of one of the two paperweights mold are shown in Figure 3. Note that in the initial mold design, risers and runners were not included in the mold for allowing the molten metal to be poured into the mold. Students had to redesign the mold to have these runners and risers added before printing the 3-D models. Figure 4 shows the 3-D mold of the gear and mounting stand combination set. Note that the gear mold had been modified to include a runner (hole) shown clearly on the bottom left mold. With the completion of the 3-D molds, the students went ahead and made the necessary preparation for the pouring of the molten metal into the mold cavities. Once the castings were sufficiently cooled, it could be removed from the molds and further evaluation of the castings could be done. Students learn first-hand what kinds of defects (see Figure 5) occurred when the molds were not made correctly; like insufficient draft angles, or the opening to the runner is too small.

From this class project involving the use of 3-D printing, the students were able to progress from the design stage to the finished product in a relatively short period of time. All in all the students were able to grasp the fundamental concepts of casting easily with the hands-on experiences gained from this class project. The 3-D printer recognizes many of these CAD drawing formats; so it is easy to print the 3-D pattern but what is important is that all the modifications on the paperweight pattern and the mold do require that the student be proficient in the use of the CAD software.

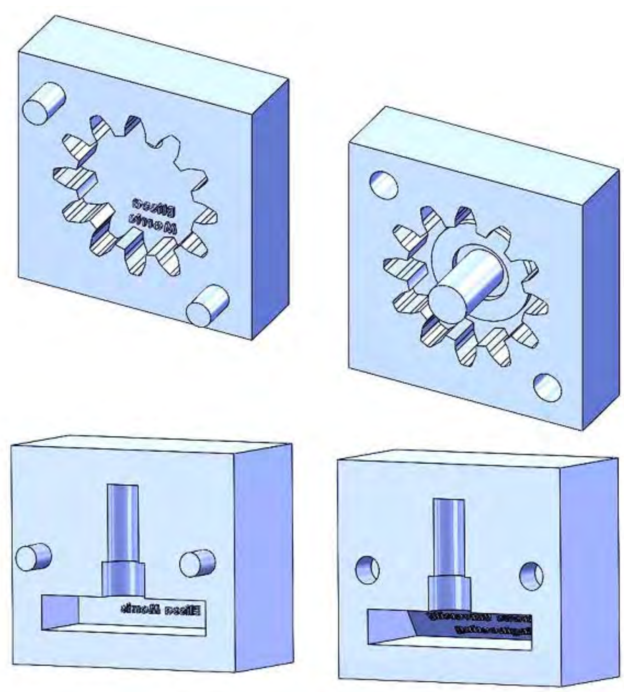

Figure 3. CAD drawing of the gear and mounting stand combination set mold. Note that there was no provision made for the pouring of the molten metal into the mold.

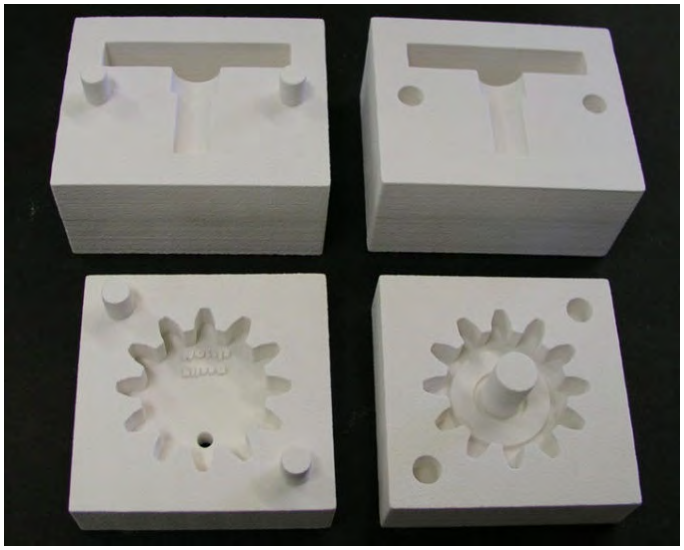

Figure 4. 3-D mold of the gear and mounting stand combination set. Note that the gear mold had been modified to include a runner (hole) shown clearly on the bottom left mold

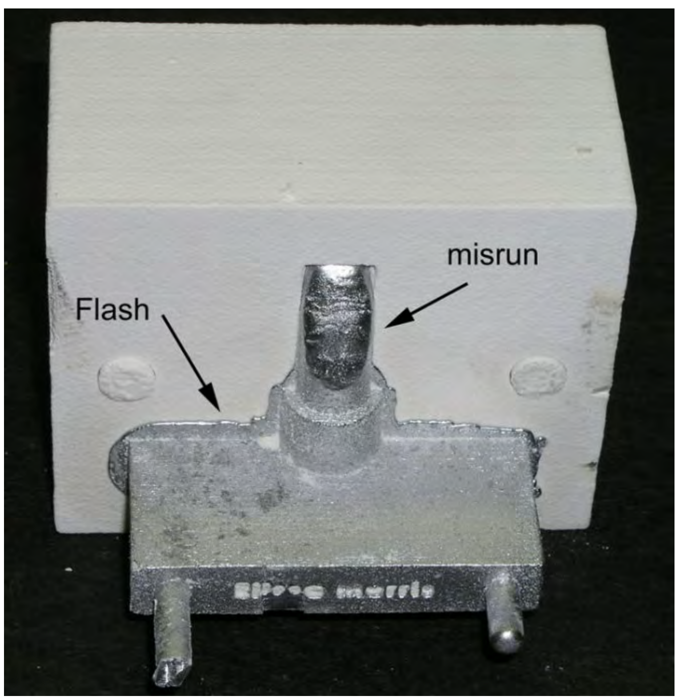

Figure 5. Figure shows a portion of the mounting stand protruding out of the mold. Misrun and flash were observed on this casting as identified by the arrow.

Machine Design: Finite Element Analysis of Machine Components

Machine Design is another upper level mechanical engineering major course. Part of this course involves the study and analysis of mechanical components. Mechanical components in the form of simple bars, beams, etc., can be analyzed quite easily by basic methods of mechanics that provide closed-form solutions. Actual components, however, are rarely so simple, and the designer is forced to less effective approximations of closed-form solutions, experimentation, or numerical methods. There are a great many numerical techniques used in engineering applications for which the digital computer is very useful. In mechanical design, where CAD software is heavily employed, the analysis method that integrates well with CAD is finite-element analysis (Budynas−Nisbett, 2011).

In this Machine Design Course, the students are exposed to some of the fundamental aspects of Finite Element Analysis (FEA), and are then tasked to analyze a load cell of the force-plate assembly (see Figure 6), using both the basic methods of mechanics followed by a FEA. This load cell assembly measures the amount of load asserted on the plate using a set of strain gages attached to one of the bars identified as B in Figure 6.

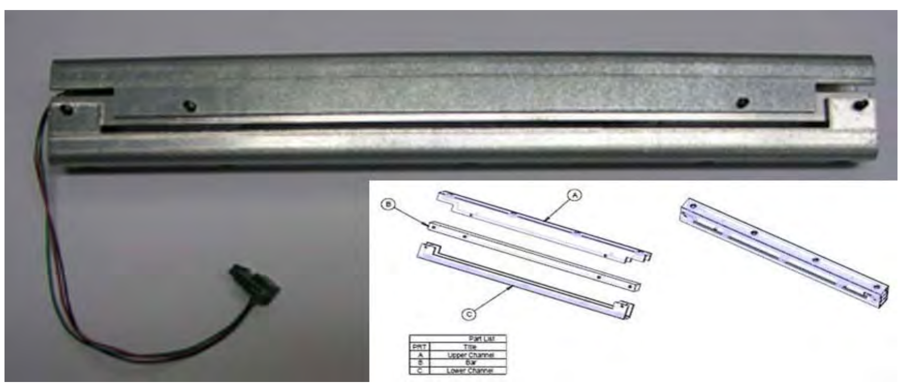

Figure 6. Image of the load cell and an exploded view of the load cell showing the upper and lower channel as well as the bar where the strain gages will be attached.

To complete the project, the students work as a team to analyze one of the components shown in Figure 6, including the pins used to mount the components together to form the force plate assembly. The students are given the blueprints of the parts (after the initial calculation by hand) to analyze the component using Algor, an FEA software.

In order to run the program in the Algor, the student will need to able to model the part in 3-D space using either one of the CAD software and importing the file to Algor or model the part directly into the Algor software which is integrated into Autodesk . In either case, the student will need to use his or her background in engineering graphics to be able to use the software effectively. Figure 7a shows the model of the bottom plate and 7b is the analyzed FEA of the plate and Figure 8 shows some of the FEA of the other parts of the load cell.

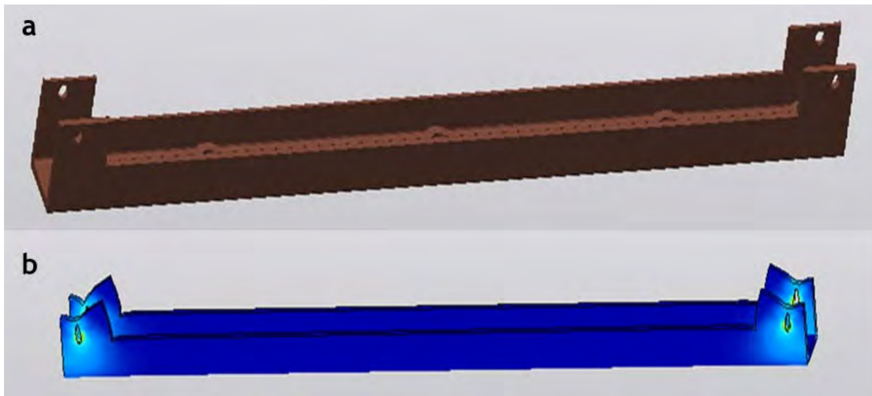

Figure 7. a) Graphic model of the bottom plate and b) the completed FEA of the same plate showing the stress concentration.

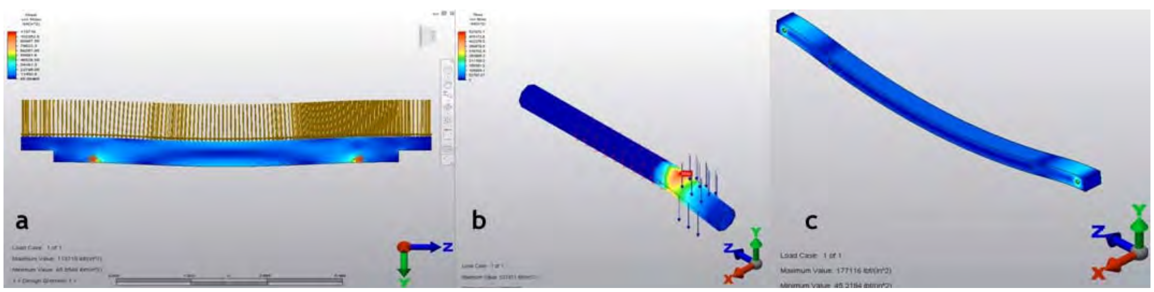

Figure 8. Various FEA of the various parts of the load cell completed; a) the loading of the top plate in the FEA, b) the FEA of the pin and c) the FEA of the center bar.

As shown in this section, skill in the use of engineering graphics software is necessary as the engineering student continues in his/her engineering program in the upper level courses. Without the proficiency skills in engineering graphics early in the engineering program, the student will have a harder time trying to complete this FEA project.

Society of Automotive: Design of Roll Cage

Each year the Society of Automotive Engineers (SAE) organizes a Mini Baja Competition to provide SAE student members with a challenging project that involves designing, building, testing, and racing a vehicle within the limits of the rules. The off-road vehicle must survive the severe punishment of rough terrain and sometimes even water at such competition.

Figure 9 shows one of the vehicles designed by the engineering students at the start of the 4-hour endurance race in Florida.

One of the important safety concerns in building such off-road vehicle is the roll cage. This cage must be designed and fabricated to prevent any failure of the cage's integrity and causing injury to the driver during collision or when the vehicle rolls over during the race. As such the student must be able to build the roll cage to meet certain criteria.

Figure 9 shows the off-road vehicle, design by students from Andrews University, at the start of the 4-hour endurance race.

In building the roll cage, students use the CAD software to model their intended design in 3-D space taking into consideration all the necessary minimum space/clearance around the driver. An isometric drawing of the roll cage is shown in Figure 10. Once the team members are agreeable with the design, they make the necessary bending of the tubes to the correct angles and cut them to the correct dimensions. This requires the student to reposition the isometric drawing in 2-D with the cages positioned in different viewing directions so that the true length and angle is shown. Figure 11 shows a section of the roll cage with the correct angles between the tubes. With a large plotter, the roll cage drawings can be printed in stages or in different viewing directions. The printed paper is then used as a template when building the actual vehicle.

This process involving the design of the roll cage to repositioning the drawings so that the correct angles and dimensions of the tubes can be measured, strongly indicates that the SAE student members must be proficient in the use of a CAD software in order to make the necessary drawings, both in isometric view as well as in 2-D space.

From these three examples, it clearly shows that mechanical engineering students must have the foundation in engineering graphics firmly grounded early in their engineering programs in order for them to successfully complete in their upper level class projects.

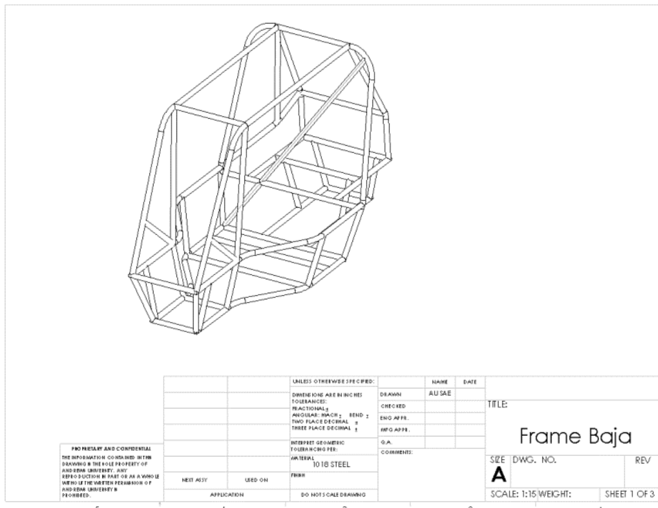

Figure 10 Isometric drawing of the roll cage used for the SAE Mini Baja Competition.

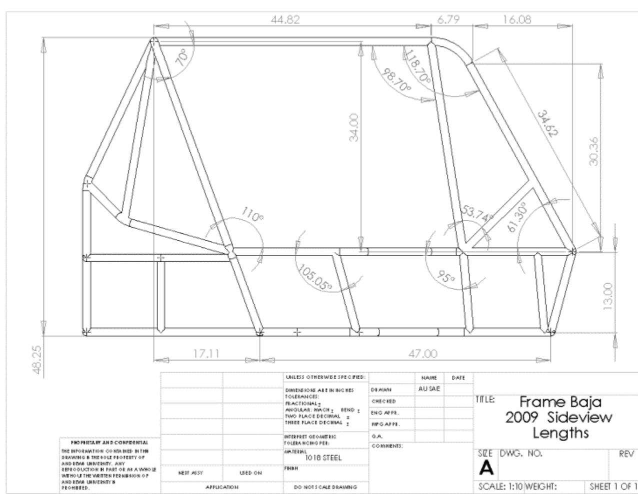

Figure 11. 2-D drawing of the roll cage showing the correct angles between the tubes.

Conclusion

This paper clearly outlines the continued use of engineering graphics in upper division mechanical engineering courses in class projects as well as in extra-curricular activities such as SAE student chapter.

- Students working on 3-D printing that involves modification of the design will need to be proficient in the use of the CAD software.
- Without the proficiency skills in engineering graphics early in the engineering program, the student will have a harder time trying to complete this FEA project.
- The mechanical engineering students must have the foundation in engineering graphics firmly grounded early in their engineering programs in order for them to complete successfully in their upper level class projects.

References

Budynas–Nisbett, **Shigley's Mechanical Engineering Design, Ninth Edition**, The McGraw–Hill Companies, Inc.

Nathan Scott, Roger Hadgraft, Vojislav (Vic) Ilic, *Australasian J. of Engng. Educ., online publication 2003-04,* http://www.aaee.com.au/journal/2003/mills_treagust03.pdf.

Michael B. McGrath, al. et., Computer Graphics , Volume 25, Number 3, July 1991.

Wiebe, E. N., Clark, A. C., & Hasse, E. V., "Scientific Visualization: Linking science and technology education through graphic communications", *The Journal of Design and Technology Education, 6*(1), 40-47, 2001.

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Virtual Reality Learning
Effects in College and Training Environments

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Abstract

The paper explains how research was conducted on desktop virtual reality (VR) in a four-year college, technical college, and industry training environments. It describes what the research team discovered to be important factors in its successful implementation of virtual reality in all three environments. The initial research project was conducted with a college and the Occupational Education Virtual Reality Research Team at Oklahoma State University with the purpose of determining the learning effects of desktop virtual reality (VR) in college and technical training. Participants in the initial study were students from a college and a career tech center surgical technician programs.

The second phase of the research was based on virtual reality as it was applied at a training center for a local industry in the Fort Smith, Arkansas area. The results from the initial research were applied as animation students developed training DVDs for industry employees. The learning effects of the industry trainees were compared to the results of the students from the classroom setting of the original research project.

The research revealed no differences in the college setting as compared to the industry training environment. Additional research is being conducted in a totally different classroom setting using virtual reality to teach welding. Results from this environment will be compared at a later date with the original and the second phase virtual reality findings.

Introduction

Virtual reality (VR) technologies are creating stunning shifts in the ways people communicate, work, and interact with each other, with information, and with technology interfaces. According to Davies (2004), VR is a "… technique of using computers to model real (or imaginary) environments in a three dimensional space that allows people to interact with the environment in a fashion that is both natural and intuitive" (p. 3). Loftin, Chen, and Rosenblum (2005) defined VR as " … technologies that provide multimodal display of and interaction with information in real time, enabling a user or users to occupy, navigate, and manipulate a computer-generated environment" (p. 749). Ausburn and Ausburn (2008a, 2008b) reported that VR can currently refer to a variety of computer-based experiences ranging from fully-immersive via complex head gear and body suits, to realistic PC-based imagery. According to the Ausburns (2008a, 2008b), all types of VR simulate or replicate a 3D environment and give users a powerful sense of "being there," taking control, and actively interacting with a space and its contents. These *virtual environments (*VEs) can immerse users/learners in a bounded graphical space and give them a strong feeling that they have actually *been* somewhere rather than just viewing it (Di Blas & Poggi, 2007; Mikropoulos, 2006).

In the original research conducted by the Occupational Education Virtual Reality Research Team at Oklahoma State University (OSU), VR technologies were used to occupy, navigate, manipulate, and control realistic computer-generated surgery environments. The studies combined theory-based quasi-experiments consisting of qualitative interviews with learners exposed to desktop VEs for surgical operating rooms (Ausburn and Ausburn, 2010). Specifically, the research conducted by the team compared the learning effects of two different types of desktop virtual reality (VR) in presenting scenes and equipment in surgical operating rooms. This technology was used in a way that supports the instruction, where adult learners can use technology to obtain information and meet their learning needs.

The results obtained from this study were then applied to the creation of a VR environment to be used in industry training. Researchers have found that the use of technology for adult literacy and education has grown with the use of the Internet and animated graphics. In the follow-up study, animators used VR applications that aided in the development of training DVDs used for a local industry. The training results were compared back to the results of the original surgery classroom study.

Review of Related Literature

This literature review builds upon research on the integration of Virtual Reality (VR) and three-dimensional (3D) computer modeling on learning and teaching. The review discusses the values and challenges of integrating visualization technologies into the teaching environment and investigates perceptions, opinions, and concerns with respect to these technologies.

Students are entering higher education increasingly computer-literate, with high expectations that they will be introduced to appropriate technologies for their subject disciplines. Academic schools are challenged by these new technologies and require appropriate strategies for their effective integration and adoption. These strategies need to be given greater awareness and understanding of innovation within the academic curriculum (Knight, 2006).

In the mid-1960s, Ivan Sutherland's thesis, "Sketchpad: A Man-machine Graphical Communications System," was introduced as a highly precise computerized drawing system. With Sutherland's computerized drawing system, this graphical tool made today's computer-aided drafting (CAD) systems possible. Since that time, the impact of computers in education has resulted in much research and application (Bridges, 1986). The initial inclusion of computer-related subjects as stand-alone modules in the structure of academic programs can offer a way for students and staff to become familiar and confident with computer applications, which would result in further appropriate integration into other subject areas (Hamza & Horne, 2006).

Since many tasks in our everyday lives depend on our ability to recognize the three-dimensionality of the environment around us, from conceptual design to the final product itself, it is important to be able to appreciate the built environment in this manner as well (Dalgarno, Heldberg & Harper, 2002). 3D modeling and especially VR are beginning to be used extensive in built environment education. 3D virtual environments can provide a rich, interactive, and engaging educational context that supports experimental learning (Mantovani, 2003).

R. Ellis explains that information technology has the potential to enhance the quality of the educational experience for all students, and ongoing work on the development of a virtual construction site project has received favorable reactions from those students introduced to new technologies (Ellis, 2006). As D. Bouchlaghem (2005) explains, "the process of design and visualization should be iterative, with changes made as a result of insights gained through visualization propagated into the next version of the design," and this "collaborative building design requires a shared understanding to be reached between all parties involved".

With 3D, 4D, and VR visualizations, "students can experiment with different 'what-if' scenarios and actively discover unique solutions to construction planning challenges" (Messner & Horman, 2003). Researcher F. Mantovani indicates "the point is no more to establish whether VR is useful or not for education; the focus is instead on understanding how to design and use VR to support the learning process" (Mantovani, 2003). With selected desktop VR and semi-immersive VR technologies as appropriate types of VR to be used by students, the approach of developing links with software companies and built environment professional practices offers real-world case studies and applications of VR that illustrates how VR technology can be applied.

Technology has the ability to assist in the teaching process, enabling students to view and interact with the concepts they are working in 3D immersive environments as shown below in Figure 1(Ausburn & Ausburn, 2004). The user employs a mouse to move and explore within an on-screen virtual environment as if actually moving within a place in the real world. Movements can include rotating the panoramic image to simulate physical movements of the body and head, and zooming in and out to simulate movements toward and away from objects or parts of the scene. Embedded individual virtual objects can be "picked up," rotated, and examined as the user chooses, and clickable "hot spots" can also be used to navigate at will (Ausburn, 2010).

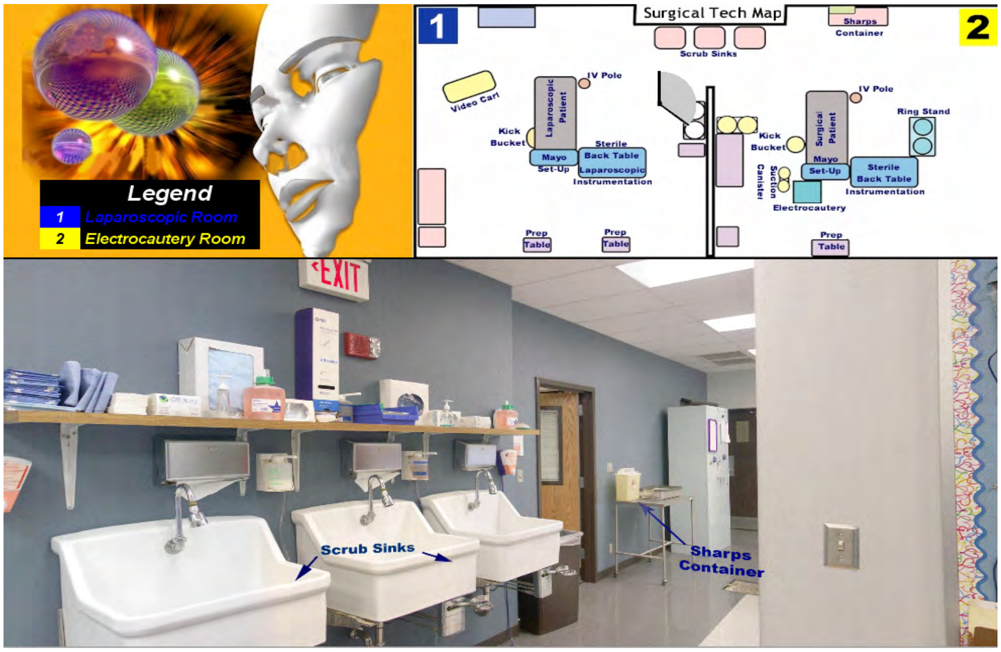

Figure 1. Desktop Operating Room VR

Based on the VR studies, three factors appear to be critical to successful VE implementation: the ability to teach VR users to understand that a VE is a complete "world" to be carefully and systematically explored, a clear explanation of the learning purpose and tasks before entering the VE "world," and adequate training and practice time in manipulating and navigating a VR program before immersion and interaction with a learning task. (Ausburn, 2010).

Administering the Research Test

For the initial research, the VR group from OSU went to a hospital's operating room to create the images for the VR scenes. The desktop operating room VR "movies" were created by taking a series of digital still photographic images and then using special VR software (VR WORKS, PANO WEAVER, TOUR WEAVER) to "stitch and blend" the images into a single panoramic scene that the user can "enter" and explore individually and interactively. The user would employ a mouse to move and explore within an on-screen virtual environment as if he or she were actually moving within a space in the real world. Movements could include rotating the panoramic image to simulate physical movements of the body and head, and zooming in and out to simulate movements toward and away from objects or parts of the scene. Embedded individual virtual objects can be "picked up," rotated, and examined as the user chooses, and clickable "hot spots" can also be used to navigate at will (Ausburn, 2010).

Each subject was given a demographic survey to complete and a copy of the *SPT1* answer sheet, which is a level of visualizing skill assessment using the Successive Perception Test 1 **(**SPT1**),** which is a video-based test that requires subjects to recall and select the screen picture**.**

The Successive Perception Test1 (SPT1) instrument was used to measure Lowenfeld's visual/haptic typology. Lowenfeld discovered that individuals with visual learning abilities had a higher chance of discriminating details that were visual. Furthermore, their reaction was also noted to be more impersonal. On the other hand, haptic learners (those with learning abilities based in the sense of touch) were not in a position to discriminate details that were visual and had a higher chance of reacting to situations with more emotions. Lowenfeld revealed that a number of individuals that were partially blind had the ability to make use of the little sight that they possessed to either view an object or apply their other senses as a way of expressing themselves. However, other individuals that were also partially blind were not in a position to utilize their eyes. These individuals found it more useful to apply touch senses (Lowenfeld, 1970).

The participant was then trained on how to operate the type of VR treatment he/she would be using during the activity. Each subject was assigned to either navigated or non-navigated VR treatments, so the VR group only needed to train each subject on how to operate one kind of presentation. It was explained to the subject that the researcher would show him/her a computer presentation that would demonstrate how to work the VR program.

The second research subjects were local industry labors being trained on OSHA safety features applied to heavy steel manufacturing. The same tests were used on the labors. The differences between the two set of data collected pertained to the VR settings. The first research was conducted in a VR surgery room and the second in a VR steel manufacturing environment.

Results and Analysis of Data

According to the posted results from the OSU VR research team (Steele, 2010), the second group of researchers also found the same results with minor differences. The results were guided by predictive research hypotheses situated in a collection of theoretical bases and supporting empirical research literature. According to Debra Steel (2011), these have included the following:

> LOWENFELD'S VISUAL/HAPTIC TYPOLOGY: Lowenfeld and Brittain describe haptic and visual styles of learning as being on opposite ends of the continuum. It has been noted that a majority of people usually fall between the two extremes. Persons that are visually oriented are not able to adapt to a given situation via means of kinesthetic and touch functions with ease. Lowenfeld has noted that as individuals advance in age, their haptic and visual perception also tends to diminish in importance (Lowenfeld, & Brittain, 1987).
>
> This may be regarded as more of a developmental effect as an increasing number of individuals turns more visual as they advance in age. Compared with other forms of perceptual styles, haptic perceptual style has a lot more significance amongst adults. Lowenfeld and Brittan state "that for some children, not only those who might be termed

extreme haptics, school may be frustrating because of the emphasis on visual learning." Lowenfeld and Brittain go on to say, "the person with haptic tendencies, on the other hand, is concerned primarily with body sensations and subjective experiences, which are felt emotionally" importance (Lowenfeld, & Brittain, 1987).

AGE AND TECHNOLOGY: Well-known research on age and generational differences in technology experience and self-efficacy (e.g., Howe & Strauss, 2000, 2003; Prensky, 2001; Tapscott, 1998) has presented evidence that these differences may relate to perceptions and performance with technology-based learning (Ausburn & Ausburn, 2010). A recent study of older adult computer users suggests there is a gender difference in anxiety levels in older adult computer users, with women displaying more anxiety and reporting less computer knowledge, despite the fact that males and females reported similar levels of computer usage (Hopey, 1999).

AGE, COMPUTER SKILLS, AND PRIOR GAMING EXPERIENCE*:* While these variables were included, the VR studies at the university found one of the limitations of the study may be the small sample size and limited range of these variables. These findings indicated that in the study between the college and OSU there were no differences in age and technology, and what was found were deficiencies in learner preparation and training for VR (Ausburn, 2010).

The results from the industry subjects were slightly different in the last area. The sample size was larger due to the extended use of the training DVDs. Four different industry locations used the DVDs making the sample size (N=134) reliable. The UA Fort Smith animation team developed the safety training DVDs based on information gained from the VRs developed by the OSU VR research team. The safety videos were created using raw animation incorporated in a gaming environment, giving the industry subjects a more realistic VR environment. The game simulator allowed the movement to be very smooth and easy to manipulate. As can be seen in Figure 2 and 3, the environments were very realistic.

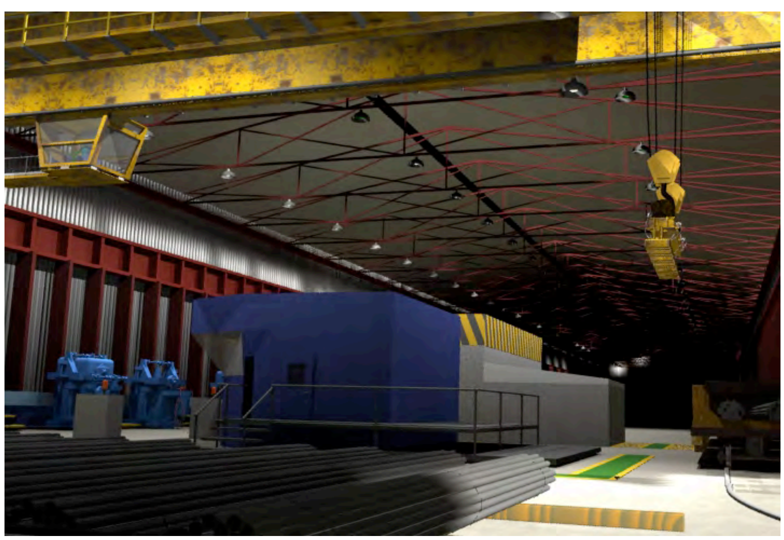

Figure 2. Main Work Floor

Figure 3. High Voltage Electrical Area

Conclusions

From both sets of data, the main question to be answered was whether age affects the levels of technophobia. There were no differences in the use of technology between the different age levels or genders observed at the two schools and the local industry.. What was found were deficiencies in learner preparation and training for virtual reality environments. The realistic environment made a big difference in the ease of use.

Additional research is being conducted in a totally different environment. The setting will be a VR for welding. The planned research will start with a basic welding environment and then expand out to under water VR environments. The results will be compared with the original findings from the OSU research team and the industry research team.

References

Ausburn, L. J. & Ausburn, F. B. (2004). Desktop virtual reality: A powerful new technology for teaching and research in industrial teacher education. *Journal of Industrial Teacher 6Education, 41* [4]. URL: http://scholar.lib.vt.edu/ejournals/JITE/v41n4/ausburn.html.

Ausburn, L.J., & Ausburn, F.B. (2008a). Effects of desktop virtual reality on learner performance and confidence in environmental mastery: Opening a line of inquiry. *Journal of Industrial Teacher Education, 45*(1), 54-87.

Ausburn, L.J., & Ausburn, F.B. (2008b). New desktop virtual reality technology in technical education. *i-manager's Journal of Educational Technology, 4* (4), 48-61.

Ausburn, L.J. Martens, J., Washington, A., Steele, D., & Washburn, E. (2010). “A Cross-Case Analysis of Gender Issues in Desktop Virtual Reality Learning Environments”. Journal of Industrial Teacher Education, Vol. 46, pp. 1-34.

Ausburn, L., Ausburn, F.B., Steele, D., Kroutter, P., Dotterer, G., et al.(2010). “Critical Elements for Successful Performance in Desktop Virtual Reality Environments.” The Hawaii International Conference on Education 1-7 January 2010.

Bouchlaghem, D., Shang, H., Whyte, J. & Ganah, A. (2005). Visualisation in architecture, engineering and construction [AEC]. *Automation in Construction 14*, [3], 287-295

Bridges, A. H. (1986). Any progress in systematic design? *Computer-aided Architectural Design Futures. CAAD Futures Conference Proceedings,* Delft, The Netherlands, pp. 5-15. URL: http://cumincad.scix.net/data/works/att/a6f1.content.pdf.

Dalgarno, B., Heldberg, J. & Harper, B. (2002). The contribution of 3D environments to conceptual understanding. *Proceedings of ASCILITE Conference, Winds of Change in the Sea of Learning: Charting the Course of Digital Education*, UNITEC, Auckland, New Zealand.
URL: http://www.ascilite.org.au/conferences/auckland02/proceedings/papers/051.pdf.

Davies, R. (2004). Adapting virtual reality for the participatory design of work environments. *Computer- Supported Cooperative Work: The Journal of Collaborative Computing, 13*(1), 1-33.

Di Blas, N. D., & Poggi, C. (2007). European virtual classrooms: Building effective “virtual” educational experiences. *Virtual Reality, 11*(2-3), 129-143.

Ellis, R., Dickinson, I., Riley, A. & Gorse, C. (2006). Virtualsite: an interface for accessing learning resources. *Journal for Education in the Built Environment, 1* [2], 15-26.

Hamza, N. & Horne, M. (2006). Educating the designer: An operational model for visualizing low energy architecture. *Building and Environment*, *42* [11], 3841-3847. URL: http://dx.doi.org/10.1016/j.buildenv.2006.11.003.

Hopey, C. (1999) Technology and Adult Education: rising expectations. *Journal of Adult Learning*, 10(2).

Howe, N., & Strauss, W. (2003). *Millenials go to college: strategies for a new generation on campus.* Great Fall, VA: LifeCourse Assocaites

Knight, P. (2006). Lessons learned from the evaluation of large scale innovation. *Leading and Embedding Innovations in Higher Education Institutions*. London: Higher Education Academy.

Loftin, R.B., Chen, J.X., & Rosenblum, L. (2005). Visualization using virtual reality. In C.D. Hansen and C. R. Johnson (Eds.), The visualization handbook (pp. 479-489). New York: Elsevier.

Lowenfeld, V. (1970). *Creative and mental growth*. New York: Macmillan.

Lowenfeld, V., and Brittain, W. L. (1987). *Creative and mental growth*. New York: Macmillan Publishing Company.

Mantovani, F. (2003). VR learning: Potential and challenges for the use of 3D environments in education and training. In Riva, G. & Galimberti, C. [Eds.]. *Towards Cyber Psychology:*

Mind Cognition and Society in the Internet Age. Amsterdam: IOS Press. pp. 207-225.

Messner, J. I. & Horman, J. M. (2003). Using advanced visualization tools to improve construction education. *Proceedings of CONVR 2003 Conference*, Virginia Tech, 24-26 September 2003, pp.145-155.

Mikropoulos, T. A. (2006). Presence: A unique characteristic in educational virtual environments. *Virtual Reality, 10*(3-4), 197-206.

Prensky, M. (2001). *Digital natives, digital immigrants.* Retrieved from http://www.marcprensky.com/writing/Prensky%20%20Digital%20Natives%20Digital%20Immigrantsw%20%20Part1.pdf

Steele, D. & Nichols, A. (2011). Learning effects of desktop virtual reality (VR) environments in college and career technical training. *International Journal of Engineering Research & Innovation*, Spring/Summer 2011, 3(1).

Tapscott, D. (1998). *Growing up digital: The rise of the net generation.* New York: McGraw-Hill.

Toward Defining *Engineering Design Graphics Journal* Goals

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Abstract

Goals are articulated and pursued for innumerable reasons: generally to achieve an end state. And it is for this reason web analytics tools, such as Google Analytics, exist. Specifically, these tools exist to collect and analyze web content data, such as those data associated with the online Engineering Design Graphics Journal, in an attempt to gain insight into how visitors use a site. Once conclusions are drawn, strategies can be fashioned to pursue the long and short term goals of the site.

Introduction

Since going online, the *Engineering Design Graphics Journal* (*EDGJ*) has experienced a decline in the submission of feature article manuscripts. As a result, the *Journal* has experienced a decline in the publication of feature articles.

In response, an initiative is underway to identify goals the *Journal* can pursue to increase the number of feature articles published in the *Journal*. To increase the number of feature articles published, the *Journal* needs to experience an increase in the number of submissions. Before identifying goals, the *Journal* needs to identify what is inhibiting researchers and other authors from submitting manuscripts to the *Journal*. Speculation on what could be curtailing submissions include the following: (a) the *Journal* charges a page fee, (b) the *Journal* requires manuscripts to be submitted online, (c) the online submission process is too cumbersome, (d) our impact factor is not calculated, (e) lack of awareness of the existence of the *Journal*, (f) the scope of the *Journal* is too broad, (g) the *Journal's* scope is too narrow, (h) engineering design graphics is no longer relevant, among others yet to be identified.

The *Engineering Design Graphics Journal*

The *Engineering Design Graphics Journal* (*EDGJ*) is the official publication of the American Society for Engineering Education's (ASEE) Engineering Design Graphics Division (EDGD). The *Journal* exists to provide opportunities for members of the EDGD to stay current with news of the EDGD and leading practices and trends in graphics education. Its scope centers on the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics in an effort to:

- Encourage research, development, and refinement of theory and applications of engineering design graphics for understanding and practice.
- Encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses.
- Stimulate the preparation for articles and papers on topics of interest to the membership (Focus and Scope. n.d.).

To these ends then, the *Journal* aligns itself nicely and provides mutual support to its parent, the EDGD—see Figure 1.

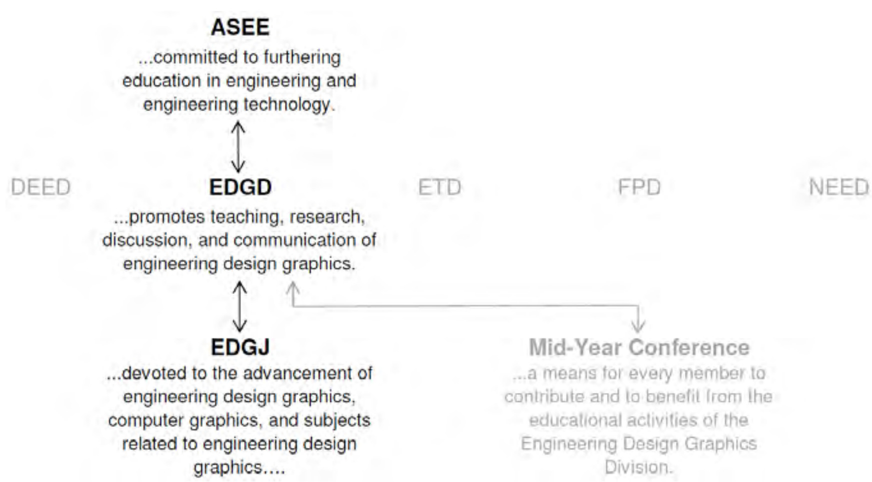

Figure 1. Mutual Support.

The EDGD exists to coordinate and promote interests and activities that pertain to engineering graphics, design and education through conferences, short courses, and through the publication of the *EDGJ*. It serves its members by

- providing leadership and guidance for those engaged in the teaching and application of graphics in engineering, design and technology;
- investigating the evolution and impact of computer graphics on engineering design graphics and informing its membership of current and future trends;
- promoting and developing ideas and providing opportunities for professional dialogue among the membership; and
- maintaining liaison with industry, government, and other professional societies (About Us, n.d.).

To these ends, the Division, like its sister ASEE divisions, aligns itself nicely and provides mutual support to ASEE, the Division's parent.

ASEE's mission is to further education in engineering and engineering technology. It does so by

- promoting excellence in instruction, research, public service, and practice;
- exercising worldwide leadership;
- fostering the technological education of society; and
- providing quality products and services to members (American Society for Engineering Education, n.d.b).

Specifically, ASEE exists to

- enhance services to its members;
- work with educational institutions and industry to improve engineering education and promote faculty development;
- facilitate productive collaborations among industry, academe, and government;
- increase the participation and success of underrepresented groups in the engineering profession;
- promote the value of the engineering profession to society;
- increase membership in ASEE in order to more completely serve the engineering and engineering technology enterprise; and
- facilitate international cooperation in matters pertaining to engineering education (American Society for Engineering Education, n.d.a).

Performance of the *EDGJ*

The *EDGJ* was first published in December 1936 as the *Journal of Engineering Drawing* ("III," 1993). It is the official publication of the EDGD of ASEE. The Division itself received formation approval from the Society for the Promotion of Engineering Education (forerunner of ASEE) in 1930. The *Journal* is published three times a year: the fall issue (formerly the autumn issue) is published in about November; the winter issue, in about March; and spring issue, in about June. And while it is not considered a core education journal, the *EDGJ* is indexed by the Education Resources Information Center.

On Aug 24, 2009, following an eighteen month self-study, the online-only *EDGJ* was launched. Prior to this date, the *EDGJ* was printed by traditional means and physically mailed to those entitled to receive issues.

The first online issue was published in the fall of 2009 (Vol 73, No 3). While it was touted as online-only, the reality is that it was online-only in that copies were not printed and physically mailed. The journal staff gave itself a year to transition from accepting manuscripts and sending them back and forth by means of email for review to going completely online with the process.

From 1987 (Vol 51, No 1) through 2002 (Vol 66, No 3), an average of 4.21 feature articles were published per issue (Chin, 2004). Between 2003 and 2009, Vol 67 through Vol 73 inclusively, either 3 or 4 feature articles were published per issue—see Figure 2. In 2010 and 2011 (Vol 74 and 75), either one or two feature articles were published per issue.

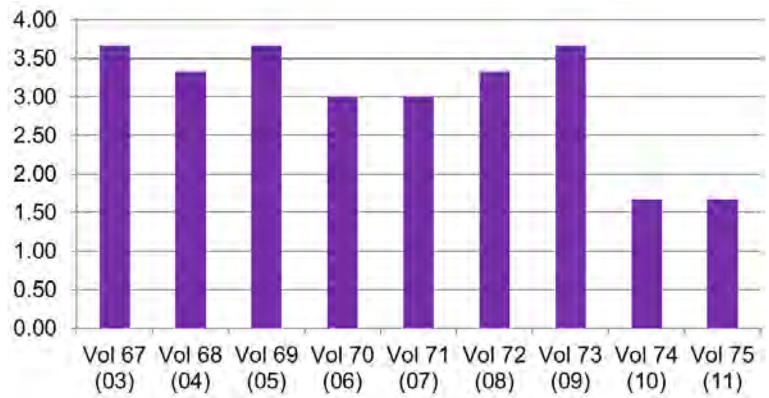

Figure 2. Number of Feature Articles Published by the *EDGJ* Recently.

For the 2006-2009, academic years, an average of slightly over six manuscripts per issue were submitted and reviewed for publication—see Figure 3 (N. E. Study, personal communication, December 8, 2011).

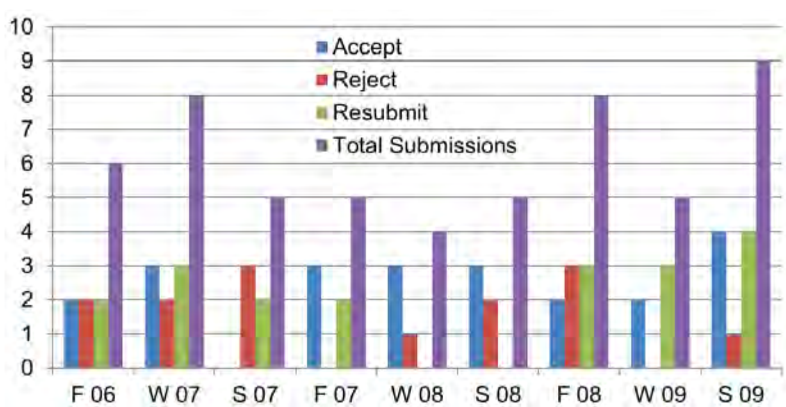

Figure 3. 2006-09 Academic Year Submissions.

In 2010 (Vol 74), eleven manuscripts were submitted for consideration. In 2011 (Vol 75), thirteen manuscripts were submitted for consideration. These data translate to an average of four manuscripts per issue submitted for consideration. This does not compare favorably with the eighteen and seventeen manuscripts submitted for consideration in 2007 (Vol 71) and 2008 (Vol 72) respectively. Moreover, the submission numbers for 2010 and 2011 (an average of four per issue) included training manuscripts and residual manuscripts that authors experienced difficulty inputting.

EDGD Membership

At the same time the *Journal* has been experiencing a decline in submissions, the EDGD has experienced a decline in membership—see Figure 4. Between 2005 and 2011, membership in the Division dropped from 282 to 214 respectively (K. Holliday-Darr, personal communication, December 13, 2011).

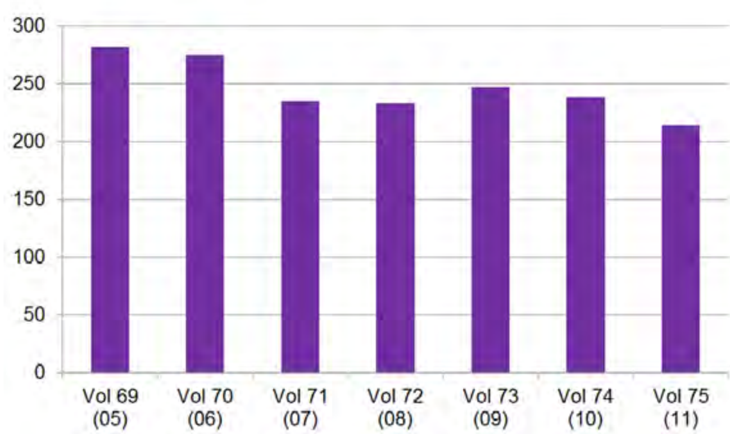

Figure 4. EDGD Membership.

While there may not be a direct relationship between Divisional membership and the number of manuscripts submitted for publication consideration, the majority of the feature articles published by the *EDGJ* are author by Divisional members.

In Pursuit of Goals and Plans for the *EDGJ*

On Sep 28, 2010, an *EDGJ* Google Analytics (GA) account was created to assess site traffic. A snapshot was taken of selected *Journal* site statistics for the 1.5 month period from Sep 27, 2010 to Nov 12, 2010 and the findings were disseminated on April 11, 2011 (Chin, 2011a). Another snapshot was taken of selected *Journal* site statistics for the three month period between Sep 27, 2010 and Dec 26, 2010 and the findings were disseminated on June 29, 2011 (Chin, 2011b).

GA offers a plethora of insight on which the *Journal* can capitalize upon to sustain its mission. As an example, while the majority of visits to the *Journal* site are from visitors in the

United States, the number of pages visited is above the site average of 3.09, the average time on site is above the 1.50 minute site average, new visits is below the site average of 84.64%.—see Figure 5. In comparison, Spain and China's number of pages visited and average time on site are both above average as well. Moreover, China's new visits proportion is above the site's average.

	Country/Territory	Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
1.	United States	6,667	5.06	00:02:50	79.38%	53.19%
2.	India	2,098	1.47	00:00:54	95.52%	77.22%
3.	United Kingdom	919	1.68	00:00:57	79.22%	68.77%
4.	Philippines	755	1.50	00:01:00	93.64%	77.22%
5.	Canada	716	1.99	00:01:02	91.76%	61.87%
6.	Australia	441	1.74	00:01:13	84.58%	69.84%
7.	Malaysia	421	1.81	00:01:28	85.04%	74.35%
8.	Germany	225	2.49	00:01:25	89.78%	64.89%
9.	Spain	222	3.12	00:02:08	73.42%	55.86%
10.	China	210	3.17	00:02:43	87.14%	65.71%

Figure 5. GA Audience Demographics by Location—Top 10 by Visits (Location, n.d.).

With respect to the pursuit of goals and plans, the Ohio Literacy Resource Center (2011) suggest that

- the pursuit of goals succeeds when they are integrated into the day-to-day plans and operations of an entity;
- plans accompanied by an implementation strategy will likely to be used;
- planning succeeds because there is a good understanding of planning steps and planning concepts; and
- planning is also likely to be successful if the process isn't handed off to a staff person and involves a commitment by an entity's leadership.

They also suggest that the pursuit of goals and planning should only be undertaken if goals and plans are likely to be implemented and if the anticipated benefits outweigh the cost to engage in planning. And they remind us that the goals and the plans are only as good as the assumptions on which they're based. They suggest that this is often the area where an entity shortcuts the process. That is, entities fail to gather the necessary information.

Conclusions

There is interest on the part of segments of the international community in the *EDGJ*. And there is low hanging fruit that can be picked. The *Journal* can capitalize on partnerships the Division began developing the last couple of years: specifically with the Design in Engineering Education Division and the Design Freshman Programs Division. Because of *Journal* authors' affiliation with other ASEE divisions and other organizations, invitations and offers to other divisions and organizations can be extended, on a regular basis, to publish their manuscripts. This initiative could also lead to an increase in Divisional membership as well as ASEE membership. And perhaps it's time to reassess the *Journal's* mission and its focus and scope.

References

III. A chronological record of the engineering design graphics division. (1993), *Engineering Design Graphics Journal*, 57, 7-15.

American Society for Engineering Education. (n.d.a). Our Vision. Retrieved from http://www.asee.org/about-us/the-organization/our-mission

American Society for Engineering Education. (n.d.b). The Organization: Who We Are. Retrieved from http://www.asee.org/about-us/the-organization

Chin, R. A. (2004). An Analysis of *Engineering Design Graphics Journal* Articles. *Engineering Design Graphics Journal*, 68(2), 6-13. Retrieved from http://www.edgj.org/index.php/EDGJ/article/viewFile/31/30

Chin, R. A. (2011a). Measuring the Performance of an Online Journal: Preliminary Findings. *Creating the Academic Culture to Educate Engineering Leaders.* Retrieved from http://155.225.14.146/asee-se/proceedings/ASEE2011/ASEE2011SE%20frame.htm

Chin, R. A. (2011b). Measuring the Performance of the *Engineering Design Graphics Journal. 2011 ASEE Conference Proceedings.* Retrieved from http://search.asee.org/search/fetch;jsessionid=287cair2pah18?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2FAC2011%2FASEE_AC2011_1318.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Engineering Design Graphics Division. (n.d.). About Us. Retrieved from http://edgd.asee.org/aboutus/index.htm

Focus and Scope. (n.d.). *Engineering Design Graphics Journal.* Retrieved from http://www.edgj.org/index.php/EDGJ/about/editorialPolicies#focusAndScope

Location. (n.d.). Retrieved from https://www.google.com/analytics/web/#report/visitors-geo/a18779345w37708257p37250885/%3F_.date00%3D20100927%26_.date01%3D20111213/

Ohio Literacy Resource Center. (2011). Why Planning Often Fails. Retrieved from http://literacy.kent.edu/Oasis/grants/fundamentals4.html

Augmented Cinematography: A Look at the Use of Augmented Reality in Film Production

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Abstract

While the use of augmented reality has become increasingly common in pre-production within the film industry, limited research exists comparing the ease of use and efficiency of a low budget augmented reality system to practical prop methods. To address this problem, research was conducted to answer the question: Does tangible augmented reality affect the perception of filming the interactions between 3D and live action elements? Participants in this study were provided with a storyboard and an animatic as a benchmark. The benchmarks depicted a character moving from the background to the foreground and the desired camera motion. They were then required to reproduce the film shot with and without the use of an augmented reality system. To determine whether the use of an augmented reality system was beneficial, the participants were asked to fill out a survey after each phase of the experiment. The survey contained questions about the difficulty of completing the task. It is desired that these results will add to the growing body of knowledge regarding the integration of 3D assets and live action film. The results of this study may be particularly beneficial to independent film makers who do not have the budget to employ the use of high cost pre-production techniques currently being used in the film industry.

Introduction

The use of augmented reality (AR) is becoming increasingly popular in the film production process. Directors such as James Cameron have begun to use AR as a tool to assist in the creation of movies with complex special effects and numerous computer generated assets (CGA) (Cameron, 2010).

Traditional methods of filming these complex special effects include the use of props. These props can range from a ball on a stick to foam or cardboard stand-ins. Filmmakers use these props to assist in the filming of the interaction between CGA and live action elements.

There are several problems with the traditional methods of filmmaking that slow down the production process. This can include the need to reshoot a scene to adjust a compositional or timing error found in post-production, which leads to unnecessary expenses. These problems are major factors in the motivation for filmmakers to attempt to use augmented reality, because it can cost them time and money to correct.

The difference between AR and these traditional methods is that augmented reality allows the user to see the computer generated assets overlaid onto the real world (Azuma, 1997). They get a real time view of the CGA while viewing the live action elements. This can allow users to compose the shot correctly and aesthetically, making sure to time accurately and test the interactions between the CGA and actor, before wasting any film (Cameron, 2010).

Although augmented reality has been used more frequently in production to help or sometimes replace practical methods, little research has been done to determine the perceptions of the director while using both systems (Robertson, 2001). This research addresses if augmented reality is a better way to perceive the interactions between computer-generated assets and live action elements. The hypothesis was defined by the current trends in the film production industry, as well as experiences of the researchers in their own film studies.

A series of subjective surveys were used to measure the perception of the test subjects while participating in the study. A summary of the testing methodology can be found in the Methodology section.

Key Terminology

180 degree rule: An imaginary line is drawn in the scene and the camera remains on one side of the line (not allowing the camera to go past 180 degrees of motion). This allows the audience to maintain a sense of where they are spatially in a scene. If the camera suddenly cuts to another side of the room, the audience becomes lost in space.

Balance: One of the rules of composition, this rule states that one should always ensure that elements in the frame feel balanced. To ensure the rough shape, color, and brightness of the primary objects complement each other.

Eye Line: One of the rules of composition, this rule comprises of placing the camera close to the line of action so the actors are facing the camera as much as possible.

Live Action: the primary capture of an image and or footage.

Panning Shot: Horizontal movement of the camera on its axis. (Rotation)

Rules of Composition: Guidelines used to help the camera operator best utilize the area of the frame and provide the most aesthetically pleasing image. These rules are general guidelines and can be compromised for specific shots.

See Also: Rule of Thirds, 180 degree rule, Lead Room, Eye Line, and Balance

Rule of Thirds: One of the rules of composition, this consists of dividing the frame into thirds along the x and y axis. This creates lines that can aid in framing a shot. The subject is then placed along the “thirds” of a scene, rather than in the center.

Tilting Shot: The vertical movement of the camera on its axis. (Rotation)

Tracking Shot: The moving of the camera from side to side. (Translation)

Traditional Cinematography

Cinematography is the art of combining lighting and camera choices that result in efficiently communicating the director's vision. Cinematographers are concerned with several very basic principles of photography to tell a visual story effectively. These principles include the rule of thirds, 180 degree rule, balance, and eye line. Ultimately the effectiveness of a shot comes down to its composition.

Composing an image in the traditional filmmaking pipeline is a matter of framing your subjects in camera while on set. When the film is developed or edited, what you record on set is what you must work with. In the case of adding a computer generated object or character into the shot, a traditional method of representing that character in frame is achieved with a prop. Props can include static stand-ins, cut outs, a ball on a stick, and any other form of visual placeholder. The director can use these props to aid in his composition and ultimately determine the success of the shot before the computer generated imagery is added in.

Problems with Traditional Methods

For all the success of the practical or traditional methods used to represent computer generated characters, there are several issues that arise from not seeing the actual character or object in frame. These issues include timing errors and framing/compositional problems.

It is possible that these problems could be attributed to the director's lack of visualization ability, but several testimonies indicate otherwise. It has been frequently documented by directors that no matter the visualization ability of any given director, being able to imagine the computer generated character is taxing and difficult to do accurately while on set. Motion shots like panning, tilting, or tracking may make it more difficult, because both a character and camera are moving independently through the scene. Since the director or the cinematographer cannot see the CG character in frame while filming, the traditional methods act more as an estimate instead of an exact representation (Robertson, 2001).

A ball on a stick might be used to represent a character on set, but it simply may not be enough to accurately frame or react to what the character might do later. Static stand-ins do not provide timing and motion information which makes the director rely on his imagination to complete the scene. Traditional methods may also hinder the spatial reasoning, especially on a blue screen set that requires extensions. It can be hard to "see" beyond the walls of the confining set (I Design Your Eyes, 2011).

Because of these problems, directors may have to use extra time and money in post-production, or reshoots, to accurately frame and create a shot. In some cases, the shots can be moved and fixed at an expense down the road, but in others, a complete reshoot may be necessary.

Augmented Reality

Augmented reality (AR) is the overlaying of real world imaging with computer generated assets (Azuma, 1997). Current uses of augmented reality include applications in education, marketing, scientific visualization, engineering, and entertainment. Most of the academic research found on the topic of augmented reality deals with collaborative meeting technologies and learning devices. This study focuses on the entertainment side of augmented reality, and more specifically, the use of AR in the film production pipeline.

Tangible augmented reality is defined as an augmented reality interface based upon a real world object acting as an input or output device (Kato, Billinghurst, Poupyrev, Imamoto, & Tachibana, 2000). Figure 1 shows an example of a tangible AR system where the card the user is holding acts as the input device for the computer generated asset.

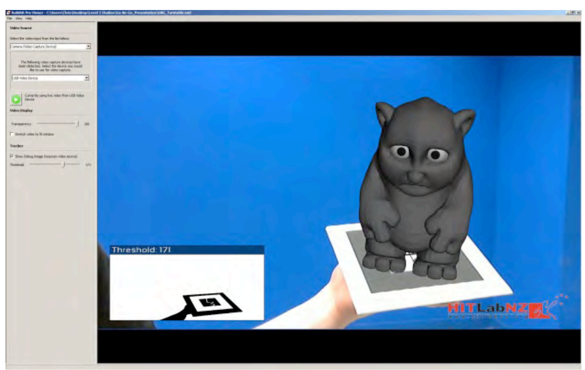

Figure 1: Screenshot from BuildAR by HitLabNZ displaying the character used for testing.

As discussed in the Problems with Traditional Methods section, the director may have a hard time visualizing the placement of the computer generated asset, which can lead to incorrect timing and framing. There are many ways augmented reality can assist the filmmaker during the production process. AR can allow the director to see the computer generated asset overlaid onto the real world environment by identifying and tracking a tangible marker (Kato et al., 2000). Animation of a computer generated asset can be incorporated into the AR software as well. The animation allows the director to worry less about estimating or guessing the timing of a particular shot. It also allows the director to choreograph camera movements in reaction to the computer generated asset. This provides a viable solution to the practical methods problem.

Professional augmented reality technologies for filmmaking can cost up to several thousand dollars, which may not be practical for independent filmmakers. However, there are several free

AR technologies that are available to the consumer. BuildAR made by HitLab NZ is one of these free technologies.

After several tests to measure its limitations, BuildAR was found to fit the parameters that were set by the researchers. For this reason, BuildAR was used to test the hypothesis described in the following section of this paper.

Problem and Hypothesis

While the use of augmented reality has become increasingly common in pre-production within the film industry, limited research exists comparing the ease of use and efficiency of a low budget augmented reality system to practical prop methods.

The question raised from this problem is: Does tangible augmented reality affect the perception of filming the interactions between 3D and live action elements?

This paper hypothesizes that the use of tangible augmented reality will affect the perception of filming the interactions between 3D and live action elements as compared to practical prop methods.

In the following section this paper will discuss the procedures and tasks completed to help test this hypothesis and answer the aforementioned question.

Methodology

The experiment discussed in this paper was conducted at Purdue University. The forty-six participants were students in the Computer Graphics Technology Department.

The participants were divided into two groups depending on the order of when they volunteered. Participant one was assigned to group A, participant two was assigned to group B, and so on. This was done so that the order of treatments could be tested to determine if there was a significant impact on the results.

Before the experiment began, the participants were given a pre-test survey to gather information on their background and experience in the use of augmented reality systems, film equipment, and film production. During the experiment, the participants were asked to film the motion of the 3D object in the scene, as demonstrated by a provided story board and animatic that illustrated the desired timing and camera motion.

Group A was first given the use of an augmented reality system, viewed from a computer on set (treatment one). Group B was first given the use of a practical prop method to film the interactions (treatment two). In this experiment, the practical method used was position markers. Position markers were chosen as the comparative practical method because they are minimally intrusive. Each group was given the discussed initial treatments and, after a designated wait period of twenty-four hours or more, switched and completed the task with the alternative method. The wait period was included to reduce the tester learning effect.

The participants were given a post-test survey to gather information on how they perceived the experience of filming the scene after they completed the task under each treatment. The questions on the survey were designed to discover if the augmented reality system made the experience easier as perceived by the participant (Figure 2).

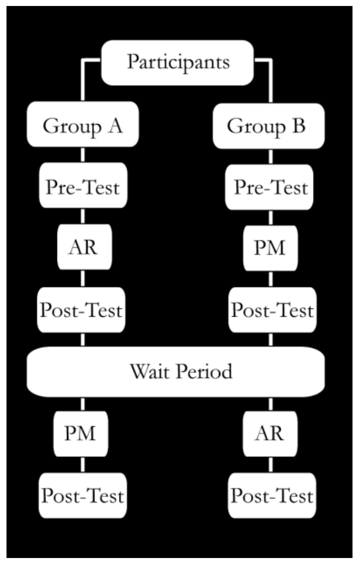

Figure 2: Testing Outline

Results

Based upon the results of the study in augmented cinematography it was determined that tangible augmented reality would have an effect on the perception of filming interactions between 3D and live action elements.

Pre-Test: Demographics

During the pre-test, the participants were asked a series of questions to gather data. Of the questions that were asked during the pre-test, three questions provided information on their prior experiences related to our testing. These three questions included the participants experience with AR, how often they used a camera in a year, and if that camera experience was in a production project.

Of the 46 participants who took part in our study, only 16 people reported they have had experience with AR in the last year. Of those 16 people, 25% have used AR once, 37% used AR 2 to 5 times, 6% used it 6 to 10 times, and 13% have used AR over 10 times (Figure 3).

All of the participants reported having experience with a camera. The majority of the participants reported using a camera 2 to 5 times within the last year (Figure 4).

While all of the participants reported using a camera, only 43 % of them have used a camera in relation to a production project (Figure 5).

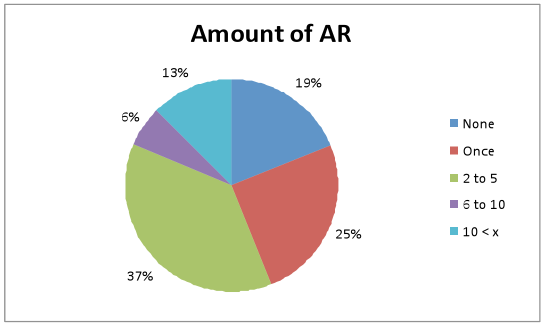

Figure 3: AR use in the last Year

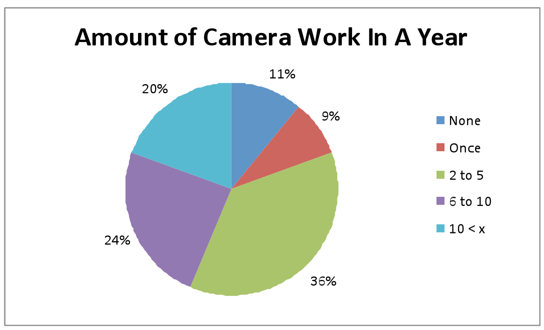

Figure 4: Amount of Camera Work in a Year

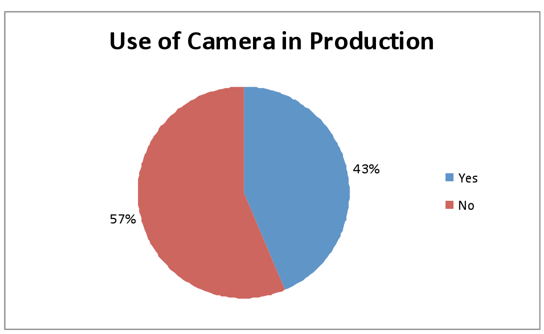

Figure 5: Camera in Production

Post-Test: Groups A & B

To compare the results of Groups A and B, both with AR and practical methods (PM), a score was created in order to emphasize their answers. Any answer that was in agreement with a statement from the post-test was given a positive score. Strongly agree answers were multiplied by positive two and agree answers were multiplied by positive one. Any answer that was in disagreement was given a negative score. Strongly disagree answers were multiplied by negative two and disagree answers were multiplied by negative one. Neutral answers were multiplied by 0 since they have no impact on the study.

After a score was created and applied for each question within each group, the totals were then put into a 2-way Anova study without replication for a statistical analysis. This was done to compare the results within the groups themselves, and to compare between the groups for any statistical differences. A 95% confidence level was used for identifying statistical significance (p-value = .05).

When the groups were analyzed by themselves, a p-value of 0.45009 was found. When the groups were examined together a p-value of 0.45361 was found. Both of these results are above the p-value set for this experiment, meaning there is no statistical difference within the groups or between the groups testing procedures.

In addition, to compare the AR data with the PM data, an average of the scored results was found. This was done to find which method had more positive (agreed) results. The average scored results for AR was 14, and the average scored results for PM was 1. Overall, AR appears to have a much higher result. When the scores were analyzed with the Anova method, a p-value of 0.04145 was found. This means that there is a statistical difference between AR and PM methods.

Trends

After analyzing the data gathered in the post-test surveys, it was found that the subjects as a whole agreed on several points. It was found that in three of the four questions asked about the character, the AR system received more positive marks and less negative than the PM.

When asked to agree or disagree on a Likert scale to the statement, “It was easy to visualize the character’s motion,” the AR system only received one disagree, whereas the PM method received fifteen disagrees and four strongly disagrees. Following the trend, when asked to do the same process for the statement, “It was easy to understand the character’s position,” the AR system received two disagrees and one strongly disagree, whereas the PM received seventeen disagrees and six strongly disagrees. Perhaps the strongest indicator of the trend was the data collected when given the statement,” It was easy to understand the character’s shape,” the AR system received only neutral or positive responses, whereas the PM received eleven disagrees and three strongly disagrees. The number of responses given here are a combination of both testing groups. However, the trend described can still be identified when looking at the groups independently.

It is important to note that the motion discussed can be separated into three simple parts; the first motion was a simple diagonal translation. The character started in the back left of the plane (position A) then moved forward and to the right, towards the viewer (position B). Once here the character rotated slightly to face the camera. The motion ended with the character rising horizontally. The shape of the character discussed can be viewed in Figure 1. Further testing will be needed to determine if the results differ with more complex motion or varied character shape.

The fourth statement to oppose this trend was, “It was easy to keep the character in frame”. A proposed explanation for this difference is offered in the Conclusions section of the paper.

Although it was not the primary focus of this study, data was collected pertaining to the confidence of the subject regarding how successfully they had completed the given task of filming the interactions. The data suggest that, regardless of the treatment, the subjects were not confident after only one take and that they were more confident after five takes using the AR system than with the PM.

Conclusion

The ANOVA comparison in the order of treatments suggests no statistical difference in the subjects’ post- test answers due to treatment order. This proves that, in this experiment, order of treatment is not a confounding variable and groups A and B can be compared as a collective data set with confidence.

The ANOVA comparison in the post-test surveys suggests a statistical difference in the subjective answers depending on the treatment received. This allowed for the rejection of the null hypothesis that states, ”…the use of augmented reality will have no effect on the perception of filming the interactions between 3D and live action elements as compared to practical prop methods.”

The comparison of the AR system and PM as discussed in the Results and Trends sections of the paper suggested that the AR system positively affected the perception of filming the interactions between 3D and live action elements as compared to practical prop methods, more specifically, as compared to the prop method of position markers. Future testing and research would be needed to make a claim regarding the comparison of more intrusive methods such as stand-ins.

A positive affect appeared in the perception of visualizing motion, understanding shape and position. The data suggested that the use of an augmented reality system makes it easier to visualize a 3D character’s motion, and easier to understand the character’s shape and position when filming as compared to the practical method used in the experiment.

As mentioned in the Trends section of the paper, the subjects contradicted the previously revealed trend of favoring the AR system when asked to agree or disagree with the statement, “It was easy to keep the character in frame." This was the only question out of the four that did not suggest a large improvement due to the use of the AR system. It is important to state that the results did not lean in favor of either treatment. An explanation of this change in trend comes from the wording of the statement and the way the AR technology works. The words "keep the character in frame" may have been interpreted differently depending on the treatment. When the subjects had the PM treatment, the character was not visible, and therefore, had to be imagined. When the subject had the AR treatment, the character could be seen on the computer monitor. However, if the AR tag that generated the 3D character and objects, or even a small portion of the tag, was not in frame the technology would stop displaying the character. It is suspected that this limitation of the technology influenced the results. It is suggested that if this study is to be conducted again, or in continuation, a multiple tag system should be used to further pursue the effects of a multiple markers system.

The research discussed in this paper did not account for an analysis of accuracy or efficiency for filming nor any kind of study on the effects of the system on actors. Instead, it was a comparison of subjective experiences of the individual manipulating the camera. The data suggested that the AR system provided a more positive experience for the individual and, thus, leaves many opportunities for further research in such areas as actor (or human) interaction, accuracy and efficiency, and confidence in task completion. The test conducted also did not attempt to study the effects of shot difficulty nor complexity of motion on the results; this would also be an important area for continued research.

References

Azuma, R. (1997). *A Survey of Augmented Reality,* Presence: Teleoperators and Virtual Environments 6(4), 355–385.

Cameron, J. (2010). *Avatar* [DVD] United States: Twentieth Century Fox.

I Design Your Eyes (2011). Zoic Studios. Behind the Scenes of "V". http://idesignyoureyes.com/2010/04/22/behind-the-scenes-of-v-zeus-explained-in-1-min-44-sec/

Kato, H., Billinghurst, M., Poupyrev, I., Imamoto, K., & Tachibana, K. (2000). *Virtual Object Manipulation on a Table-Top AR Environment.* International Symposium on Augmented Reality. Munich, Germany.

Robertson, B. (2001) Inside Moves, Computer Graphics World. Volume: 24 Issue: 7. [ILM provided for film "A.I."]