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WIP: Incorporating GDT into Engineering Graphics Courses

Steven Nozaki (Assistant Teaching Professor)

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Nancy Study

Dr. Nancy E. Study is an Associate Teaching Professor in the School of Engineering at Penn State Behrend where she teaches courses in engineering graphics and rapid prototyping, and is the coordinator of the rapid prototyping lab. Her research interests include visualization, standardization of CAD practices, and haptics. Nancy is a former chair of the ASEE Engineering Design Graphics Division, and is currently the Editor and Circulation Manager of the Engineering Design Graphics Journal. She received her B.S. from Missouri State University, and M.S. and Ph.D. from Purdue University.

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Abstract

This work in progress describes efforts to enhance the pedagogy in engineering graphics courses with respect to geometric dimensioning and tolerancing.

The Mechanical Engineering Technology curriculum at Penn State Behrend includes several courses in engineering graphics, covering topics ranging from hand sketching to advanced techniques in computer aided design. One of the topics in the advanced course is geometric dimensioning and tolerancing (GDT).

Anecdotal findings suggest that students have difficulty contextualizing content regarding GDT within the environment of class. Most students enrolled in the course have limited, or no, exposure to manufacturing methods and tools at the time they take the course. There are currently no artifacts generated or manipulatives incorporated when teaching GDT at Penn State Behrend. This is not unusual per se, as many other topics in the engineering graphics curriculum are predicated on visualization as a primary means of interpretation.

Educational materials specifically designed for GDT study have been procured by faculty for curriculum development, which includes content and manipulatives that illustrate concepts in GDT. This work in progress paper will document the attempts to incorporate aspects of the GDT material in the course. One specific change will be to include examples across the scope of the course, instead of the current one-week segment of the course.

A long-term goal of the faculty will be to develop a course in GDT that pertains to the specific needs of the department and school. Input from external sources to the school, including recent feedback from the industrial advisory board, has indicated interest in students developing proficiency in GDT. Results from this study will be used to influence decisions made in course development.

Introduction

The Mechanical Engineering Technology (MET) department at Penn State Behrend attempts to continuously improve its pedagogy and performance outcomes in a variety of ways. One component is to have industrial advisory board (IAB) meetings, where stakeholders from industry meet to discuss their needs and how the MET department can better prepare students with relevant skills. One topic that has been recurring in discussion by members of the IAB, and conveniently timed for development, is Geometric Dimensioning and Tolerancing, or GDT. GDT is a common facet in engineering technology curricula, often incorporated into a class on measurement or engineering graphics. Less common, is an entire course dedicated to the topic of GDT.

There has been ongoing discussion at Penn State Behrend to develop a standalone GDT course as a technical elective. As a part of the development process, preliminary testing of activities will be done to study the feasibility of those activities. Periodically, opportunities arise to implement changes that are compatible with planned course activities. This paper will examine the first such attempt at incorporating those activities in an existing course and expanding the discussion to the GDT/engineering graphics community.

Literature

Geometric Dimensioning and Tolerancing (GDT) is a method of describing parts based on how they function using a standardized set of symbols [1]. GDT considers the use of a part and how it will function with other parts. Doing this can allow for increased accuracy without making tolerances more demanding. GDT is often first introduced to students in first-year courses where they have little experience in manufacturing or machining processes.

There is extensive research on manipulatives increasing the effecitiveness of STEM instruction at K-12 levels [2][3][4][5]. Theories pertaining to specific subjects are explained in each area, though a common theme in them is manipulatives' ability to provide a concrete example of an abstract idea. For example, children learning about addition may better make cognitive connections with blocks or coins, or chemistry students could better grasp molecular structures with spheres, rods, and connectors. Manipulatives can thus help illustrate new, unfamiliar ideas by linking them to established concepts. It seems to be explicitly prevalent for manipulatives to be a constant pedagogical narrative in STEM at the P-12 levels.

Previous research has shown that students who self-select into engineering and engineering technology majors score at or above the mean in haptic tendencies as measured by the Haptic Visual Discrimination Test (HVDT) [6],[7]. The test is a standardized and quantitative test that measures a subject's skills in tactile sensitivity, spatial synthesis, and the ability to integrate partial information about an object into a whole. The test can be used for all age groups which allows for interpretation of results based on normed data [8]. While many graphics courses are taught primarily with the use of images to instruct on the topics of multiview projection, missing lines, missing views, dimensioning standards, and so on, it has been found in multiple studies [9],[10],[11] that the use of manipulatives in combination with traditional graphics instruction methods, improves student outcomes including visualization skills, especially for those students who may enter the course with lower visualization abilities.

GDT is a topic that has little practical reference to most first-year students, including those at Penn State Behrend, who typically have no experience in manufacturing or machining at the time they take the graphics course in which GDT is introduced. Even when teaching the topic to upper-division students and including the inspection and measuring of parts using calipers and CMM activities, outcomes can be varied. "In general, students appeared to perform better on items that required them to Remember, Understand, or Apply than on items which required them to Analyze, Evaluate, or Create" [12], and in future offerings of the course in that study, there will be additional emphasis on thinking through the process and group discussions. This is supported by the idea that manipulatives help control the connections of one's mind and solidify abstractions by providing a situated example [13]. When implementing outcomes of prior research on GDT instruction, and considering engineering and technology students' haptic tendencies, the use of physical objects in instruction on GDT could enhance understanding of a topic that is difficult to portray simply with visual images.

Proposed Methods

In the second graphics course, there are approximately 2 weeks dedicated to the areas of tolerancing and GDT. Both graphics courses are at the 100 level and content had been appropriately scaled. Currently, the material is largely theoretical, consisting primarily of literature and the application of symbols on CAD models and drawings. Topics in tolerancing and GDT are presented and discussed in lecture. In lab sections, students interpret graphical information to produce engineering drawings of parts and assemblies with GDT information.

One of the perceived issues of the authors is the lack of context that GDT topics can present. Students taking engineering graphics courses are typically in their first 3 semesters. Many students have little to no experience in the field, much less dedicated practice of GDT. GDT controls range from relatively simple to very involved. In Figure 1, the text used for the class [1] describes the control of flatness, in which a feature shall remain flat between two theoretically parallel and uniform planes. Figure 2 shows a relatively more complex control of Surface Profile, in which a three-dimensional tolerance zone is evenly measured through the entirety of the shape. One can see from the examples the amount of information that can be conveyed in a relatively concise symbol.

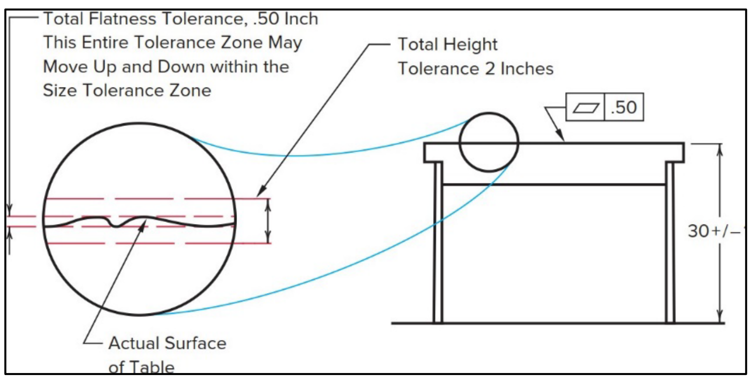

Figure 1 GDT description of "Flatness"

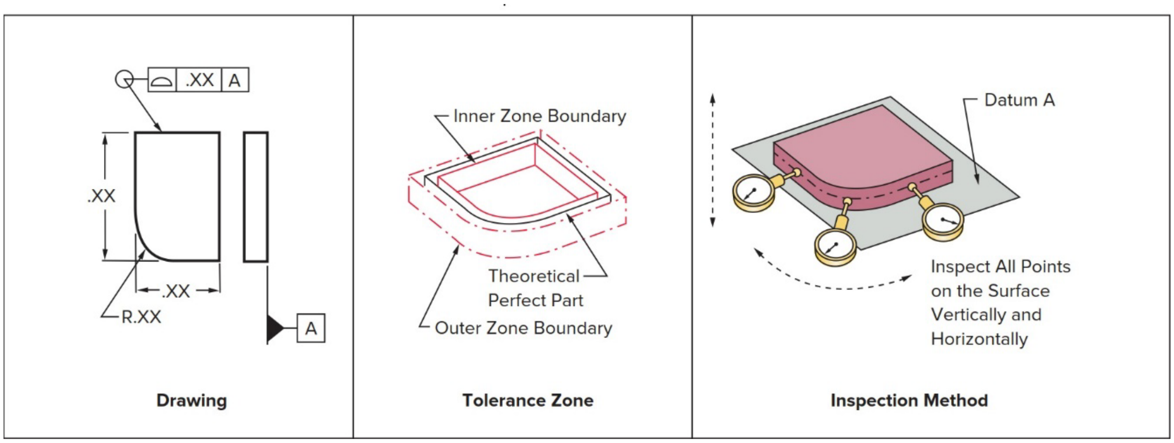

Figure 2 GDT Description of "Surface Profile"

There are a variety of methods to categorize educational goals and abilities, such as one prevalent system used in engineering education research, Bloom's taxonomy [14][15]. Tools like Bloom's taxonomy can be utilized to characterize learning objectives for lesson planning and larger curriculum development. To try and enter a higher cognitive domain, increased skills to utilize GDT were sought out. Replicating GDT and tolerances from an existing plan arguably falls into entry level domains of Knowledge, where students memorize symbols and can recall the steps needed to create a drawing in the assigned CAD package.

A common exercise in GDT education is to translate a sentence describing a condition to the appropriate symbols. This illustrates the consistency and accuracy of standardized GDT symbols. An example sentence describing the position of a hole may be as follows:

> "The axes of the holes shall be positioned in a 10 thousandths of an inch cylindrical tolerance zone at least material condition relative to primary datum feature A and secondary datum feature B."

If this condition was something a designer wanted to communicate in words, one could surmise that the detailed nature could lead to the creation of a variety of statements with varying degrees of accuracy. One can see then, that the corresponding symbols in the feature control frame in Figure 3 stands to make the interpretation of design intent much clearer by reducing the need for possibly ambiguous text.

Figure 3 Sample GDT

This activity of translating words into GDT symbols encourages students to interpret design intent and create the appropriate symbols. However, there are few contextual clues that can help situate the knowledge being created. That is, it is still just words and symbols. In a previous work by the authors, a grant allowed for the procurement of a curriculum geared toward learning GDT with the goal of developing a standalone course [16]. Part of the content includes artifacts, tools, and manipulatives for use in a lab setting. Examples of the manipulatives can be seen in Figure 4.

Figure 4 GDT Manipulatives

One of the goals of the project will be to include GDT examples throughout the semester. This will be done primarily through demonstrating modeling strategies and examples. Including examples means not only showing a tangible shape when creating solid models, but also incorporation of the vocabulary used. It is thought that repeated exposure to a topic can help prepare students for future activities and opportunities to learn [17].

A proposed classroom activity will be to provide similar manipulatives to students for exercises in GDT. Having an object that relates to the situation will hopefully increase the ability of students to generate accurate GDT symbols. Manipulatives will be provided with statements attached, and it will be the students' responsibility to create a drawing with the appropriate symbols. Conversely, a manipulative could be provided, and students could generate possible relevant GDT symbols for manipulatives.

Discussion with members of industry has helped conceived an idea for manipulatives to be contextual to the student population on campus. Manipulatives contained in GDT learning modules often are idealized versions of specific instances[16]. This is to be expected, as a perfect model would foreseeably help focus on the GDT control being measured. Introducing an artifact from industry – plastic injection mold parts, gear sprockets, shaft and hole systems, - that have GDT requirements included could help situate learning the abstract principles of GDT, as well as contribute to the discussion on related technical subjects. An extension of this would be to source artifacts from the field that illustrated instances of when GDT constraints were not held and effects were manifested in failure, wear, breaking, and so forth. This kind of sourcing would take considerable effort by educators. Not only is a thorough understanding of the topic necessary, the ability to communicate conditions of desired artifacts is necessary to those able to procure them

– then furthermore include them in educational activities conducive to learning. One goal of the authors will be by communicating this idea with the engineering graphics community, it will initiate dialogue and trigger the exchange of ideas.

Discussion and Further Plans

The MET department at Penn State Behrend is currently undertaking extensive revision to the curriculum to bring it more in line with the needs of industry whilst still meeting the requirements of ABET accreditation. Part of this revision includes updating the engineering graphics courses with additional instruction in GDT, reinforced with related content across the curriculum so the students are exposed to the content in multiple ways across multiple courses.

In the spring 2022 semester, manipulatives were used by instructors to demonstrate a variety of GDT concepts including location, circularity, cylindricity, and flatness. However, at the time the topics were being addressed in the course, the campus was still operating under COVID-19 protocols that prohibited the sharing and handling of materials between students in the classroom. The instructors used a document camera and projector for the demonstrations so students could see the objects but did not interact with them. Data is currently being collected to see whether classwork and exam scores were impacted, but anecdotal evidence from positive student comments during the demonstrations, and fewer questions about how the feature control frames were applied and measured, indicate at least slightly positive outcomes.

In preparation for future semesters, manipulatives will be created for use in the graphics class during the section on GDT. To compare the new instruction to previous attempts at teaching GDT, similar lessons will be utilized with the only change being the presence of manipulatives. Informal formative assessment of students' perception of the topic will be the primary metric of the effectiveness of manipulatives. A secondary metric will be the comparison of student performance in previous semesters that did not have manipulatives. Artifacts are being sourced over the spring and summer of 2022 to be used in the off-sequence offering of the graphics course that covers GDT. To allow for more manipulatives to be considered, a priority will be placed on sourcing artifacts that are existing rather than parts that are by-design to have issues with GDT. This will reduce the resources needed to generate unique, one-off artifacts. At this point, efficiency on artifacts will not be a focus – i.e. having artifacts that embody multiple GDT controls – but rather, the mere acquisition of said artifacts.

As this paper is a Work in Progress, one of the goals of the conference will be to engage in dialogue with the engineering graphics community. The study will be conducted during the initial review process, with more information to facilitate discussion available at the time of the conference.

Note: Due to the ever-changing COVID-19 health protocols, the Penn State Behrend campus may have to modify the implementation of manipulatives in class. Ideally, it would be advantageous to be able to distribute and rotate manipulatives freely among students. As such, procedural limits will be utilized in efforts to comply with campus' suggested guidelines for safety (e.g. disinfectant wiping of parts between uses, limit manipulatives to pods of students, and so forth).

References

[1] G. R. Bertoline, E. N. Wiebe, N. W. Hartman, & W. A. Ross. (2010). *Fundamentals of graphics communication*. McGraw-Hill Higher Education.

[2] Marley, S. C., & Carbonneau, K. J. (2015). How psychological research with instructional manipulatives can inform classroom learning. *Scholarship of Teaching and Learning in Psychology*, *1*(4), 412.

[3] Thompson, P. W., & Thompson, A. G. (1990). Salient aspects of experience with concrete manipulatives.

[4] Kontas, H. (2016). The Effect of Manipulatives on Mathematics Achievement and Attitudes of Secondary School Students. *Journal of Education and Learning*, *5*(3), 10-20.

[5] Cohen, H. G. (1981). The Use of Manipulatives and Their Effect on the Development of Spatial Conceptualizations.

[6] N. E. Study. (2008, June) Testing the haptic abilities of a sample of minority engineering and technology students. Proceedings of the ASEE Annual Conference & Exposition. Pittsburg, PA.

[7] N. E. Study. (2001). The effectiveness of using the successive perception test I to measure visual-haptic tendencies in engineering students. Unpublished doctoral dissertation, Purdue University.

[8] L. McCarron, & J.G. Dial, (1979). Sensory integration: The haptic visual processes, Dallas, Texas: Common Market Press.

[9] N.L. Veurink,, A.J. Hamlin, J.C.M. Kampe, S.A. Sorby, D.G. Blasko, K.A. Holliday-Darr, J.D. Trich Kremer, K.S. Harris, L.V. Harris, P.E. Connolly, M.A. Sadowski, C.P. Brus, L.N. Boyle, N.E. Study, T.W. Knott. (2009). Enhancing Visualization Skills-Improving Options aNd Success (EnViSIONS). The Engineering Design Graphics Journal, 73 (2) 1-17.

[10] N. E. Study (2006, June). Using remediation to improve visualization abilities in minority engineering and technology students. Proceedings of the ASEE Annual Conference & Exposition. Chicago, IL.

[11] N. E. Study (2011, June) Long-term impact of improving visualization abilities of minority engineering and technology students. Proceedings of the ASEE Annual Conference & Exposition. Vancouver, BC.

[12] T.J. Branoff. (2018, June), Evaluating Concepts Presented in a Geometric Dimensioning and Tolerancing Course Paper presented at 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah. 10.18260/1-2—30444

[13] Howard, P., & Perry, B. (1997). Manipulatives in primary mathematics: Implications for learning and teaching. *Australian Primary Mathematics Classroom*, *2*(2), 25-30.

[14] J.B. Arneson, & E.G. Offerdahl. (2018). Visual literacy in bloom: Using bloom's taxonomy to support visual learning skills. *CBE Life Sciences Education, 17*(1), ar7. https://doi.org/10.1187/cbe.17-08-0178

[15] A. Sharunova, Y. Wang, M. Kowalski *et al.* Applying Bloom's taxonomy in transdisciplinary engineering design education. *Int J Technol Des Educ* (2020). https://doi.org/10.1007/s10798-020-09621-x

[16] S. Neumann, & A. Neumann. (2009). GeoTol pro: *A practical guide to geometric tolerancing per ASME Y14.5-2009 (1st ed.)*. Society of Manufacturing Engineers.

[17] D. McAvoy. (2010, June). A repeated exposure experiment to improve knowledge retention. In *2010 Annual Conference & Exposition* (pp. 15-81).