Introducing Cooperative Learning into a Fundamental Mechanical Engineering Course

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Abstract

In our institute, Geometric Dimensioning and Tolerancing (GD&T) is a core course offered to junior students majoring in manufacturing, mechanical engineering and mechanical engineering technology. Due to the features of GD&T, learning effectiveness for the students tends to be low. In order to address this issue, for the first time in public domain, cooperative learning was introduced in GD&T education. The result is encouraging. The students showed great interests in learning GD&T and eagerness in applying it in their future careers. In this paper, the author will discuss how a cooperative learning environment is set up in a fundamental mechanical engineering class. The possibilities of improving and extending such a learning style to other engineering courses will also be discussed.

Keywords: Cooperative learning; Engineering education; Geometric dimensioning and tolerancing.

1. Introduction

Geometric Dimensioning & Tolerancing (GD&T) is a core course offered to junior students majoring in manufacturing, mechanical engineering and mechanical engineering technology. It introduces symbols that specify functional relationship between or within part features [1]. Some of the GD&T symbols are shown in Figure 1. These symbols have specific rules that impose a direct bearing on how the part must be manufactured, assembled and inspected [2]. GD&T is a fundamental mechanical engineering subject and is essential to manufacturing and mechanical engineering [3].

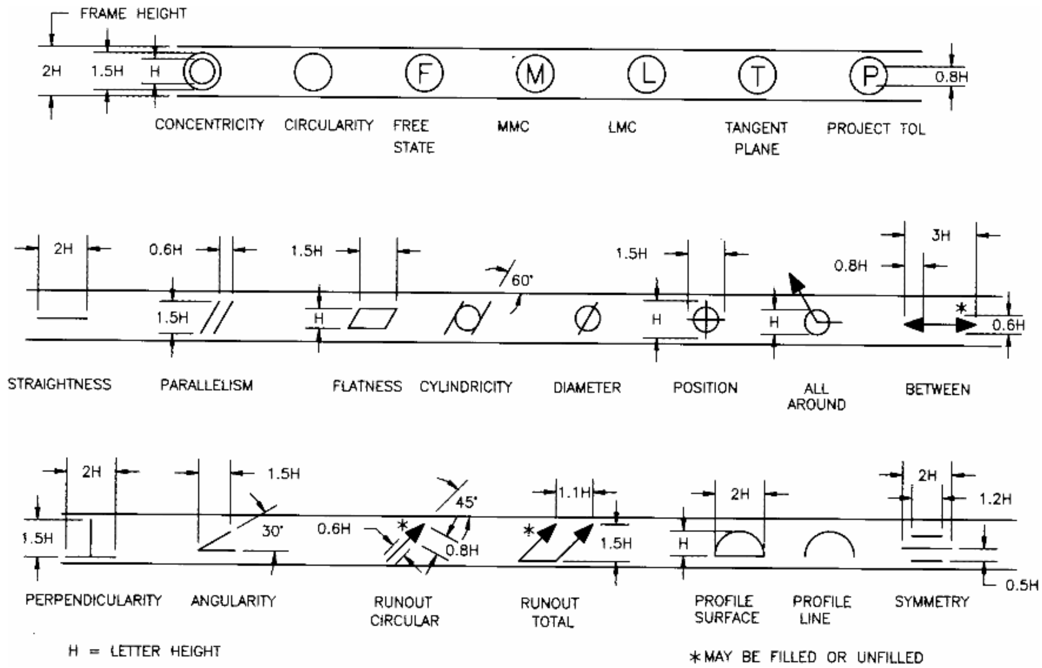

Figure 1. Some GD&T symbols [3].

The author of this paper began teaching GD&T in 2005. To improve the students' learning effectiveness in GD&T, cooperative learning was experimented. In this paper, the author will discuss how the cooperative learning environment is set up in the class. There are five sections in the paper. Following the Introduction, Section 2 will discuss the challenges that the students face in GD&T learning. Section 3 will introduce how these challenges can be addressed by using cooperative learning. Section 4 will include the class evaluation after cooperative learning is applied. The conclusions will be summarized in Section 5.

2. Challenges in GD&T learning

Engineering drawings are legal documents and need to be formal and precise. GD&T is a technical "language" that is contained in engineering drawings. It forms a document that communicates an accurate description of a part. GD&T is a subject about symbols, rules and principles and has a couple of unique challenges.

Firstly, GD&T is an abstract topic and hard to visualize. Figure 2 is an example of a homework assignment. It illustrates a simple part. GD&T symbols, such as flatness, positional tolerance, total runout, parallelism, perpendicularity, and basic dimensions are all over the place in the drawing. The associated tolerances (i.e. allowable variations in dimensions) control the quality of the part. Even though the students do not have the chance to see the tangible part personally, they still need to have a clear understanding of what all the GD&T symbols stand for in the drawing. Moreover, they should be able to design experiments to inspect all the indicated tolerances.

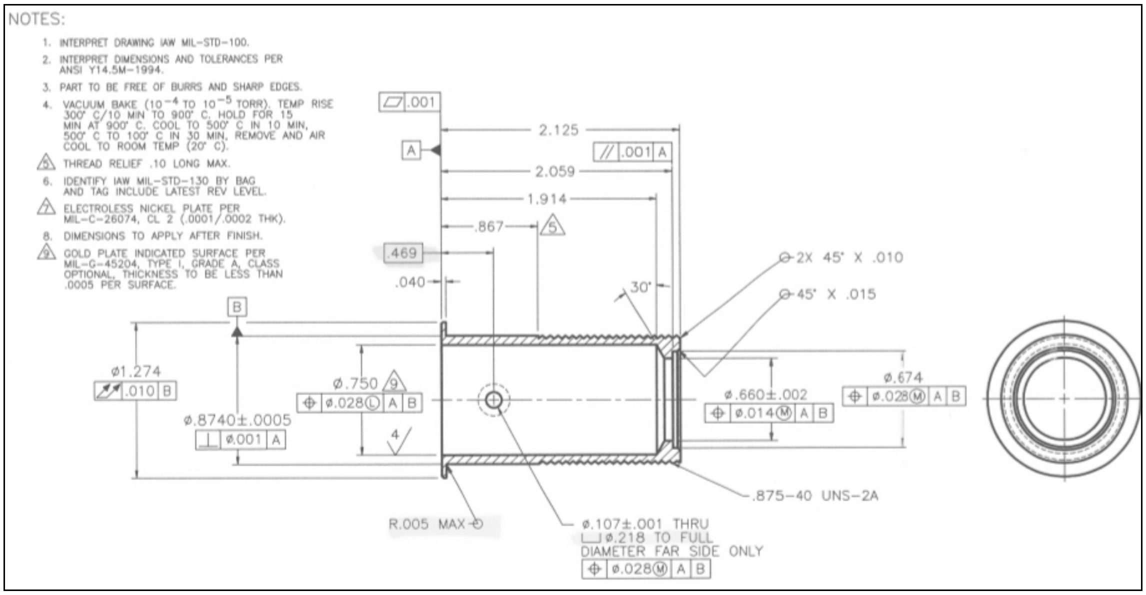

Figure 2. An example where GD&T is used in engineering drawing [3].

Secondly, GD&T is a multi-disciplinary topic and hard to practice. It combines mechanical design, manufacturing processing, metrology, and quality control together. So far, there has been no comprehensive design project (e.g. senior or capstone project) in our institute to put GD&T into practice. Once the students take the GD&T course, they may not have the opportunity to use it until they graduate and start working in industry.

Therefore, GD&T was regarded as a highly-theoretical and time-consuming course by the students. When the course was first taught by the author in 2005, there were more than 10% students who were the dropouts from previous academic quarters.

3. Establishment of cooperative learning in GD&T

Cooperative learning is an instructional paradigm which involves students working in teams to accomplish a common goal [4,5]. Five required elements distinguish cooperative learning from other forms of group work [6,7]:

- Positive interdependence: students believe that they can not succeed without teamwork;
- Individual accountability: performance of each student on the team is assessed; each member is aware that one individual cannot rely exclusively on others;
- Face-to-face interaction: students discuss the concepts, teach each other, and explain solution procedure in their own way;
- Collaborative skills: students must acquire social skills, such as leadership, time-management, conflict resolution and communications;
- Group processing: regular group discussion is set aside to assess team functioning.

Research shows that cooperative learning has been successful in various engineering classes [6,8-14]. Cooperative learning has become an alternative to traditional lecture-based teaching style. The major benefits of applying this model are summarized as follows:

- It increases students' understanding of the subject matter;
- It improves thinking and problem-solving skills by encouraging interactive learning;
- It forces students to practice team and small group communication and teamwork skills which are a must in the real world;
- It increases students' confidence in their capabilities;
- It improves instructional productivity.

These benefits motivated the author to experiment with cooperative learning in GD&T. Three strategies were developed to set up the new learning environment. The first strategy was to enhance communications among the students so that they could learn from each other more frequently. The second strategy was to strengthen hands-on experience in a group setting so that GD&T rules and conventions could be better learned. The third strategy was to collaborate with senior projects so that the students could conduct research to see how GD&T could be applied in manufacturing practices. These three strategies were implemented by five approaches: 1) group formation, 2) group presentations, 3) group work to study GD&T instruments, 4) cross-training among groups, and 5) group research.

Group formation

On the first day of class, the students were asked to form small study groups. Normally, each group consisted of three to four students and four groups could be formed for the whole class. One special feature with the students in our department is that a considerable amount of them are industry professionals (from JELD-WEN Inc., Boeing Inc., etc.) and have substantial experience from the real world. When groups were formed, these students were asked to be the group leaders. Through their leadership, two significant impacts were produced. Firstly, their professional experience in GD&T was shared with the whole class, and every student benefited from it. Secondly, the group leaders set up role models by bringing professionalism (e.g. punctuality to finish assignments, communication skills, presentation ability, and teamwork.) into group activities.

Group presentations

The first group activity in GD&T was to help the class to review. After each chapter of the textbook [3] was taught, a group was selected to prepare a five- to ten- minute presentation. Each group had two to three chances to present different chapters during the entire academic quarter. The presentation was a summary of the chapter just taught and every presenter was individually assessed by all other groups. As shown in Figure 3, the grading rubrics were based on four considerations:

- Completeness: does the presentation cover the major topics of the chapter?
- Understandability: is the presentation easy to follow along?

- Helpfulness: is the presentation good enough to help form a general picture of the chapter?
- Participation: does every team member actively participate in the presentation?

Grading Rubrics for MFG 314 (GD&T) Review Presentation

Grader's Name: ____________________

Presenters	**Completeness** (5 points)	**Understandability** (5 points)	**Helpfulness** (5 points)	**Participation** (5 points)

Figure 3. Presentation grading sheet for GD&T.

In the presentation, everyone in the class was free to ask questions, and the presenting group was responsible for further clarifying ambiguities. After the review, the whole class was quizzed on the chapter.

<u>Group work to study GD&T instruments</u>

The second group activity in GD&T was to study how to use instruments to measure tolerances. GD&T learning is heavily dependent on hands-on experience. The more opportunities to practice, the more deeply can the students understand the concepts, rules, and conventions. Besides learning how to use optical flats, gage blocks, sine bar, and sine plate, the students focused their group activities on two major instruments: optical comparator (as shown in Figure 4), and coordinate measuring machine (as shown in Figure 5). These two machines are more complicated and sophisticated than other instruments and the learning curve is high for individuals.

Figure 4. A student working with Optical Comparator.

Figure 5. A student working with Coordinate Measuring Machine.

The whole class was divided into two big groups and each group took two weeks to learn one instrument. A group report was required and the following tasks should be completed:

- Learn the instruction manuals of the instrument provided by the vendor;
- Develop a simplified instruction manual for proper use of the instrument (the students are encouraged to record the operation steps by video camera);
- Compile a trouble-shooting manual for instrument maintenance;
- Use the instrument to finish tolerance measuring assignments.

Group environment helped the students to quickly grasp the essence of the instruments. Meanwhile, the report, manuals, and video clips enriched the knowledge base of this course by providing a good training resource for the current and future students.

Cross-training between groups

The third group activity in GD&T was cross-training between groups. After a team was finished with the study of one instrument (say, coordinate measure machine), it exchanged the training materials (video clips, instruction, and trouble-shooting manuals) with the other group (which studied optical comparator). Then, two groups spent another week to cross-train each other.

The cross-training result was tested by the instructor at the end. Some machine parts and their engineering drawings were given, and the students were asked to measure the tolerances. As illustrated in Figures 4 and 5, two students were demonstrating in front of the class during the cross-training test.

Group research

The fourth group activity in GD&T was group research. In this activity, the students studied product prototypes provided by senior projects of our department. They did research from various aspects, including product functionality, quality requirements, machining, and assembly process. After that, the students put forward GD&T specifications for product quality improvement. Figure 6 illustrates a product prototype produced by a senior project. When it was first made, there was no GD&T specification. By the time this paper is written, a group of GD&T students are working with the senior students who made the prototype on adding tolerance requirements to it. Group research gave the students an opportunity to fully apply their GD&T knowledge into real manufacturing practices.

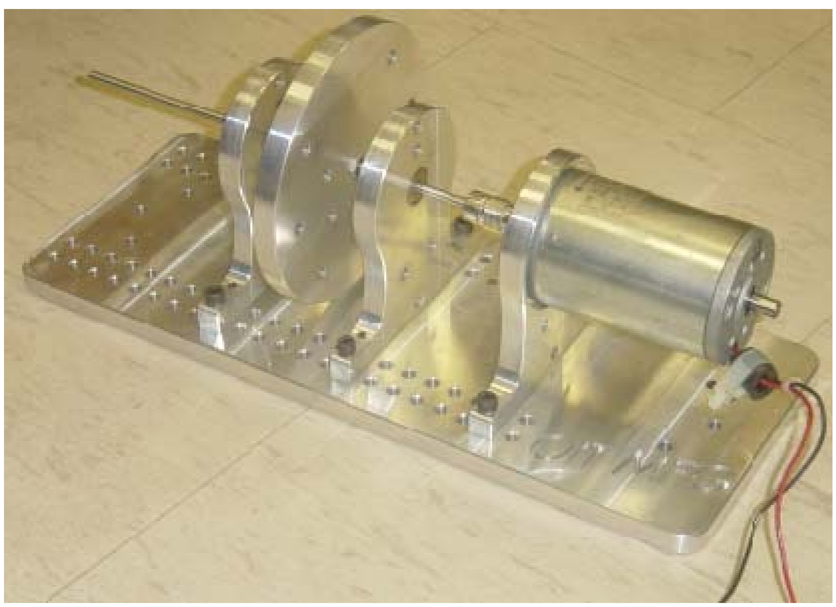

Figure 6. A product prototype the students studied in group research.

4. Evaluation of the class

After cooperative learning was introduced, the time allocation for an average student in GD&T obviously changed. As illustrated by Table 1 the proportion of group activities (55%) is considerably more than that (20%) before cooperative learning was used.

Table 1. Time allocation before and after cooperative learning is used in GD&T.

Activities		Time Allocation	Traditional time Allocation
Individual-based	Lecture	20%	30%
	Reading & homework	20%	40%
	Quizzes & exams	5%	10%
Group-based	Lab	30%	20%
	Presentation	10%	-
	Cross-training	10%	-
	Group research	5%	-

Cooperative learning effectively motivated the students to get involved in GD&T learning process. The students gave a very high evaluation (4.4 out of 5.0 for the last quarter) to this class, and here is some of their feedback.

- "I think the teams do good."
- "Have more team assignments rather than individual ones."
- "Continue team work/assignments."
- "It gives us a chance to learn multiple ways of explaining a problem."
- "It helps me remember what I need to be studying."
- "I think team presentations are helpful in two ways: those giving presentation get an in-depth review; the rest of class benefits from their fellow students' findings."

The exams used in GD&T are based on the ones recommended by the textbook. Cooperative learning has been used in GD&T for three terms already. So far, all the students have successfully passed the exams with the majority of them receiving A's and B's.

4. Conclusions

The primary goal to implement cooperative learning is to make the learning process more efficient by reasonably smoothing the learning curve for the students. The author found that two steps are involved to switch a fundamental mechanical engineering class into a cooperative learning environment:

- Strategy-making: identify major issues and set forth appropriate cooperative learning strategies to address them;

- Implementation and evaluation: develop specific group activities and assessment tools so that the teamwork can be undertaken and evaluated effectively.

Cooperative learning is a successful pedagogical model for engineering education. The author is putting efforts to improve and extend such a learning style in two aspects. The first aspect is to increase the proportion of group activities in the current GD&T course. The second aspect is to implement cooperative learning model in other engineering courses he teaches. By the time the paper is written, cooperative learning is being implemented in Computer Programming for Engineers, which is a freshmen/sophomore programming class. In the future, it will be implemented in other lab-intensive engineering courses, such as Manufacturing Information Systems, Industrial Simulation, etc.

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