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Case Studies of Authentic Learning Tasks Method Applied in Industrial Technology

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Abstract

The Authentic Learning Task (ALT) was initiated by the National Center for Manufacturing Education (NCME) sponsored through a National Science Foundation (NSF) project as a means of studying subject matter through hands on projects. Recently, more and more professors recognize and advocate this method because of better engagement and comprehension for students using hands-on projects. This paper describes two case studies of the ALT projects applied in two different courses, namely Advanced Computer Numerical Control and Statistical Quality Control, at a four-year Manufacturing Technology Program. Step-by-step instructions are presented on how the ALT projects were organized, implemented, and evaluated in the courses. The paper also includes student feedback which is useful for further refining and improving the design of a similar ALT project. The experience shared in this paper will benefit college instructors who are in similar circumstances by making the teaching/learning of technical concepts more interesting and effective.

Background and Motivation

The manufacturing sector is an important contributor to the U.S. economy. It accounts for 22-25% of the gross domestic production and this percentage has not changed much for over the past 50 years (Shinn, 2004). Annual earnings of salary and benefit packages for manufacturing employees averaged $65,000 in 2004, which was 21% higher than the overall average for all American workers (National Association of Manufacturers, 2006). It has been recognized that maintaining a sustainable manufacturing industry not only leads to increased productivity, societal prosperity, and well-paid jobs, but also ensures a competitive economy and national security.

The rise of the service industries based upon information technology together with some negative public perceptions such as low wage, manufacturing job layoffs, international outsourcing, and global competition (Hunt, O'Sullivan, Rolstadas, Horan & Precup, 2004) discouraged young generations to pursue manufacturing careers (Wei, 2005). Low enrolments experienced in some colleges eliminated some manufacturing-related programs. On the other hand, the American manufacturing industries are facing a shortage of highly qualified employees with specific educational backgrounds and skills (National Association of Manufacturers, 2006). In Iowa, which is traditionally recognized as an agricultural state, manufacturing facilities generate over 21% of the Gross State Product (GSP), which places Iowa 8^{th} nationally in terms of the importance of manufacturing to the state economy. According to the Center for Industrial Research and Service (2008), the annual wages and salaries of Iowa's manufacturing workers rank the 2^{nd} highest by the major sector in the state's economy. Like the rest of the states in US, however, the lack of adequately trained workforce turns out to be the biggest challenge facing Iowa's advanced manufacturing firms in the next 10 years (Battelle Memorial Institute, 2005). It is necessary and critical for educators and researchers in manufacturing technology areas to create new strategies to update the traditional manufacturing curriculum and to make it more attractive, effective, and competitive.

Traditional engineering/technology courses usually consist of lectures, assignments and examinations, and these are taught one subject at a time with little connection or integration between subjects (Higley, 2003). To a large extent, it is hard to engage students' attention by using this teaching pedagogy. It has been reported that the hands-on, activity-based teaching/learning strategy has provided obvious advantage in science, technology, engineering and mathematics (STEM) education due to students' high level of engagement and comprehension (Kolar & Sabatini, 2000; Liou, Allada, Leu, Mishra, Okafor, & Agrawal, 2002). Verma, Bao, Ghadmode, and Dhayagude (2005) reported in their study that physical simulation increased student participation and better understanding of the manufacturing concepts. This strategy is particularly necessary for manufacturing technology or engineering programs where students need comprehensive training in various technical subjects, including theories, practice and application.

The Authentic Learning Task (ALT) method was initiated and promoted by the NSF-sponsored National Center for Manufacturing Education (NCME). The ALT method is beneficial for students in manufacturing-related programs wherein the students are assigned a task in a hypothetical machine shop to simulate the activities in real work scenario. Students will have to think creatively and independently by integrating the technical concepts they have learned from various subjects such as engineering design, math calculation, critical analysis and evaluation in completing theses tasks. In addition, since the ALT method is usually conducted based upon teamwork, students' personal skills such as self-discipline, communication, teamwork, organization, and leadership will also be trained before going to work in a real manufacturing context. After undergoing the training at NCME the authors introduced this method to a Manufacturing Technology program in a four-year college.

The ALT method was tested in two completely different courses, namely Advanced Numerical Control and Statistical Quality Control. Because the ALT method was used in two different courses, the format and style of the descriptions for the two case studies are different. Through the two cases presented in this paper, readers can see how the ALT method can be adopted into different subject disciplines to simulate real industrial projects in the classroom setting and how this pedagogical tool can benefit the teaching and learning in manufacturing technology education.

Case Study I - Selection of CNC Equipment in Advanced Numerical Control

Selection of a Computer Numerical Control (CNC) machine tool for a given application is a complex task requiring a large amount of information. Though there are many options available for a given application, users need to evaluate a number of factors to find a feasible and economical selection of a CNC machine tool. This ALT project helps in identifying those features and helps students in understanding various facets of a CNC machine tool selection process. In the following, the ALT project is described step by step along with expected solutions and conclusions drawn from students' performance. Instructors may use this as an example to formulate their own class projects.

Project description

This is essentially a group activity to help foster the idea of working in groups and use the collective wisdom of the group members as well as to distribute the workload between the members. A maximum of three members for each group was allowed and the groups were made with voluntary assignment. Each of the group was provided with a spectrum of components that need to be manufactured along with a range of specifications as follows:

- Engineering components. (Proj. A: Prismatic parts that are to be essentially made on machining centers, similar to housing for gear boxes, differential housing, brake master cylinder, steering pump, control arm, swivel bracket, flywheel housing, etc. Proj. B: Parts same as Proj. A. The project involves making the dies to manufacture these parts for mass production. The diecasting dies and sheet metal dies are required for these parts. So it is essentially a tool room project. Proj. C: Mostly axis-symmetric parts with some of them having milling features such as cross holes and flats.)
- Total number of different parts is 100 per year with production volumes of 500 each.
- Materials: Steel, Cast iron, Aluminum
- Medium batch sizes (typically about 100 each)

Step 1: Analyses of part geometry

Based on this information the students are expected to identify the characteristics of the machining operations required. Students need to make suitable and valid assumptions since the detailed drawings are not available at this stage. The first step is the analysis of part geometries. The following are some of the observations inferred from the part geometries:

- Prismatic parts
- Small to large size
- Variety of materials
- Complex geometries
- Large machining time
- Part size varies from 3 in to 23 in
- Most of the part sizes are lower than 17 in

Step 2: Identify the machining requirements

- Large parts can be catered by one large machine while all the others can be done on smaller machines.
- All can be machined using 3-axis machines. There is no need to go for 5-axis machines.
- Total machining time required needs

to be estimated based on some suggestions.
- Since no data about the feature geometry is available, there is a need to make assumptions.

Step 3: Calculate machining time

At this point a complete part drawing would greatly help, but may not really be available at the time of planning. Thus, there is a need to estimate the required machining time. The actual machining time required is calculated as follows:

- Assume average part machining time = 45 minutes
- Total machining time requirements = 100 × 500 × 45/60 = 37,500 hours
- Hours available for one machine = 8 × 250 = 4000 hours per year
- 250 days per year = 365 – 52 × 2 (Sat & Sun) – 11 (National holidays) = 250
- Number of machines required = 37,500 / (4000 × 0.85) = 11.029 = 11 machines
- 1 large 3-axis machining centre (24" × 24" ×15") + 10 small machining centers (18" × 18" ×15")

These requirements will change if we decide to work for 2 shifts per day.

Step 4: Comparison and selection of major machine tools

The students will be collecting information from manufacturers and distributors about the various machines available to satisfy the requirements. Students are provided with the names of various major manufacturers in the country and their web site addresses to jump start the information collection process. The following are some of the manufacturers considered in the project: Bridgeport, Chiron, Cincinnati, Lamb, Deckel Maho (DMG America), Gidding and Lewis, Hardinge, Haas Automation, Huller Hille, Hurco, Index, Kitamura, Makino, Mazak, Mikron, Mitsui Seiki, Mori Seiki, Okuma, Rohm, and Tribute.

Information to be collected is the basic characteristic of the machines as well as their prices. The cost needs to be determined based on the base machine and the accessories that are needed. As the cost for all the machines was not readily available from their respective web sites, correspondence with the distributors for information did not yield much success. That was a limitation because not all the distributors responded to the students' requests. The students were provided with a template for comparison of the different CNC machine options. An example template is shown in Table 1.

From these comparisons the students were able to select the machine tools that would be required for the purpose. Then the students designed all other support services required for establishing a machine shop with the entire support infrastructure.

Conclusions

1. The students were able to get a good exposure to a wide range of machine tools that are available in the existing market.
2. They were also able to understand the process of evaluating the machining requirements and the associated problems when the information available is insufficient.
3. They were able to think like entrepreneurs in developing the required infrastructure in addition to the main machine tools to complete a full machine shop.
4. The major challenge that students faced was lack of complete information and the ready cooperation of the machine manufacturers/distributors. If the information were available, the students would have felt more excited for doing such a challenging and useful project.

Table 1: Comparative evaluation of different CNC turning centers

	Haas SL-20	Hardinge Quest 10/65	Okuma ES L10
Max. part size (in)	10.3 × 20	9 × 19.6	12.20 × 19.68
Spindle power (hp)	20	20	20
Spindle through hole (in)	3.00	2.935	3.15
Controller	Haas (Similar to Fanuc)	GE-Fanuc 21i-T	OSP-U10L
Floor Area required (in)	92 × 55	118 × 76.5	100.4 × 76.9
Max. Spindle RPM	4,000	6,000	3,000
Max X-axis traverse speed (in/min)	1,200	1,100	787
Max Z-axis traverse speed (in/min)	1,200	1,500	984
Accuracy (in)	±0.0002	±0.0002	±0.00059
Resolution	±0.0001	±0.0001	±0.0001
Repeatability (in)	±0.0001	±0.00005	±0.00012
Tool turret	10 stations	12 stations	12 stations
Square tool shank size (in)	1.0	1.0	1.0
Turret index time (sec)	1.0	0.1	1.1
Net weight (lb)	9,000	12,240	8,377
Base Cost ($)	51,995		

Case Study II - Gage R&R Project in Statistical Quality Control

Producing parts with excellent quality and reasonable cost is critical for manufacturing businesses in the current era characterized by global competition. Students in manufacturing related majors need to be well versed in the fields of quality control, six-sigma, and total quality management. Statistical quality control is one strategy included in the total quality management arena. The usage of data through enumerative study to reveal the quality status is the major objective established in the course of Statistical Quality Control. Students will learn how to make decisions according to statistical data results instead of subjective opinions.

Measurement data is often used in manufacturing practice to make a decision to accept or reject a component part, subassembly, assembly, or finished part. The decision made is only as good as the reliability of the data, which means the measurement system, including the appraiser, equipment, and measurement setup, must be able to provide valid data. In addition, a randomization approach is important and is commonly practiced in statistical control and analysis because it can help eliminate the possible biases. Students are always at a loss in understanding this concept and are not familiar with the randomization procedure. In this ALT project, collecting their own data through randomization, students will use the gage R&R method to evaluate the measurement system practiced in industry and further to make recommendations based upon the result. Student team formation, project description, and students' performance and learning effectiveness analyses are parts of the gage R & R case study.

Team formation

Students conducted this gage R&R project in teams. In total, six teams consisting of two or three students formed in a random manner. All the names of the students were written on separate sheets of paper. To form a group, three pieces of paper were drawn randomly from the lot.

Project description

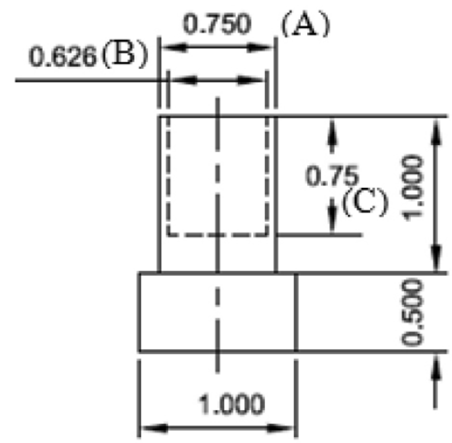
The lab assistant produced ten identical aluminum parts (specified by a few dimensions shown in Figure 1). He has many years of machining experience and is familiar with the operation of turning machines in the production lab. Again, six groups were randomly assigned to measure one of three dimensions: A, B, or C. A vernier micrometer with a least amount of 0.0001inches was required to collect measurement data. To encourage students to have independent thinking, 10% bonus credit could be applied to a project if students chose to use their own products that are different from the project turned parts. To select a proper quality characteristic for a product and establish a valid measurement system to conduct the gage R&R study, students need to answer the following questions with comprehensive thinking and decision-making:

- What characteristic should be measured?
- Is the selected characteristic critical to evaluate quality for the part?
- What equipment needs to be used?
- Is the equipment appropriate in collecting data?

Answering these questions needs to consider something more instead of only following the instructor's direction. To help students conduct a valid gage R&R study, some guidelines were provided such as:

- The group should provide enough parts (no less than ten parts) to provide variation necessary for analysis.
- The parts should have some consistency (provided by the same vendor or produced by the same operator).
- The group should use the same measurement equipment in data collection.
- The group should identify the quality characteristic for evaluating the product.
- The group should select an appropriate measurement device that can capture enough characteristic variations.

Figure 1.Turned aluminum parts prepared for the gage R&R project



The activities students need to conduct in the gage R&R study included: making a detailed data collection plan through randomization, collecting data according to the defined plan, calculating, evaluating and analyzing the data through Microsoft Excel, providing analyses and interpretations of the analysis result, and making relevant recommendations based on data analysis result. Students should submit a project report including an executive summary giving the major finding, which will be read by a busy manager in a short period of time. If students decided to use their own product, the first task would be choosing a quality characteristic for their specific product and designing a corresponding measurement system including scientific measurement equipment, setup table and operational instructions of how this quality characteristic should be measured.

Student performance and follow-up analysis

Positive experiences

It has been found that the bonus incentive was effective in motivating students' learning. In the beginning, the instructor was apprehensive that students would feel reluctant to find measurement objects. That is the reason for having ten identical parts prepared in the study. When designing this ALT gage R&R project, the instructor would like to include presentation as one of the activity tasks. Due to only one type of prepared parts, students would not be engaged well and might feel bored when listening to six similar presentations about one same topic. Actually, all of the groups found their own products and quality characteristics such as weight of fishing egg sinker, weight of flying arrow contained in the game box, resistance of 10-ohm resistor, thickness of flat washers, and outside diameter of cartridge castings. After the experience learned in this project, the instructor will enhance the gage R&R ALT project next time by adding requirements of presentations and using different products.

Generally, it appears that students showed improved mathematic skills in this team project. Mathematic calculation is a big issue for many students because of using statistics. When grading the gage R&R homework assignment, the instructor found that around 50 percent of the students had made mistakes. One acute problem was dealing with long formulas that require multiple levels of mathematical operations. In this ALT project study, only one group made a calculation mistake. Whereas when the students were doing individual assignments there were many calculation mistakes. It appears that students working in teams seem to learn and correct from each other to improve their math skills. Next time all individual students will need to take a mathematical test after they conduct the gage R&R project to verify this interference.

Students indicated improved interests in learning statistics and quality control principles due to software application and the ALT approach. Matching with the textbook *Quality Control* (7th ed., authored by Dale Besterfield), Microsoft Excel was used as a computing software package in this class. In the beginning of the class, a survey was conducted to determine students' Excel level. The survey indicated that a few students knew Excel, but only had very little experience in using Excel for calculation. Most of them did not know either the built-in functions or charting techniques in Excel. During the class, students were fascinated to learn these powerful computing functions. Though no quantitative tests were made, the instructor recognized students showed improved capability in using Excel from observing their class performance, and homework and project responses. In the beginning of the semester, students were slow (some even frustrated) in using the Excel computation functions; with practice, students expressed more confidence. On the other hand, they displayed, to some extent, lower interests in understanding and interpreting the statistical data results in lecture and homework. Students did not experience any data collection process, since all the data was given for the gage R&R homework problems from the text book. What students could do was to follow the gage R&R cutoff guide line to determine whether or not the measurement system should be accepted or needs to be improved.

In this gage R&R ALT project, students did a great job in data analysis and interpretation because they designed their own measurement system and experienced the entire data collection process. All the groups provided interpretations and recommendations after analyzing the data, some of which were really constructive and creative. For example, the group measuring the weight of the flying arrow recommended "should put the arrow on the center of the scale; having the arrow centered on the scale could eliminate error caused by the scale being out of balance". This group also recommended "using a V-block to eliminate error caused by the arrow rolling around; the V-block could be weighted by itself and then zeroed out for every measurement". The group measuring the outside diameter of the cartridge casting found that their gage R&R percentage far beyond the allowed cutoff value. Their reflection was written as "reproducibility is much larger than repeatability, which tells either the operator needs to be trained in using and reading the gage, or we need to implement a fixture to help the operator use the gage more consistently". This group also tried to give a better operational definition of how the product should be measured, such as "we need to consider compressing the cartridge as we take our measurement; not being perfectly horizontal with the caliper on the cartridge could be a problem".

Students gave very positive feedback about the ALT approach. Students included their learning reflection in the report. One group wrote, "It is one thing to sit in class and punch data into Excel spread sheets and display the finding and it is a totally different thing to actually get the raw data and see where the calculations are coming and what they represent". Another group said, "Doing this project gave us a hands-on approach to all of the different formulas that we have learned. By doing this project from start to finish we got to see exactly how the process works from putting the washers into a random order, to measuring each one to analyzing the data we received. This can be a tedious project even for just some simple washers. Having different appraisers does make a difference in the measurement. The two of us were measuring the same part but our results were not always the same."

Issues to be addressed in the future

Indeed, problems still occurred in one group that interpreted the gage R&R study result in a wrong way. From this observation the instructor felt that fundamental principles and procedures of the gage R&R study need to be further emphasized. Enhancing and training students' math skills is important and teaching students to learn how to evaluate and analyze by applying quality control principles is even more important.

Another observation from this study is the requirement for the students to be trained in writing technical reports and executive summaries. The executive summary should be written to include data analysis result from this enumerative study as key findings to support their decision and recommendation. Two groups did not mention their statistical data result as findings in the summary. Students had difficulties in technical writing such as proper usage of written language instead of using too much oral language, APA format, grammar, misspelling, and some other issues because of not paying sufficient attention.

Overall, students displayed more motivation and engagement in this gage R&R study. The vast majority of students' performances were satisfactory. A great improvement on math skills can be seen through the comparison of students' individual homework and the group project calculation result. This project helped students with a better understanding of fundamental concepts applied in statistical quality control such as randomization, variation, repeatability and reproducibility. Some enhancement ideas were generated in this gage R&R study so as to make an ALT gage R&R project more interesting and more effective for teaching/learning the gage R&R concept.

Conclusions, Significance, and Limitations

Practicing the ALT method, students in the two courses made a better connection between textbook knowledge and the practical applications. In the selection of the CNC machine tool project, multiple-disciplinary knowledge is required to solve the problem, such as: machine tool feature analysis, part feature analysis, production planning, economical analysis, evaluation, comparison and decision making. The gage R&R project helps students with a better understanding of fundamental concepts applied in statistical quality control such as randomization, variation, repeatability and reproducibility. Due to the real measurement and data collection, students showed more interest in learning the math skills that were used in the study. The students' performance and reflection indicated that the ALT method was an effective approach to enhance STEM education. The authors are to try to share the teaching experiences with colleagues through the case studies presented in this article. Other instructors may use these projects in their classes or created their own ALT projects to make manufacturing related topics not just about formula, but also about fun and activities.

With the effectiveness and experience achieved in the ALT methods, more activities will be designed and incorporated in the manufacturing technology curriculum in the near future. A research proposal focused on curriculum and lab improvement to strengthen STEM education has been submitted through the use of ALT method. Essentially, it is hoped that this teaching approach will help increase the enrollment of manufacturing programs in the US and provide more trained professionals with suitable skills to make sustainable contributions to the US economy because of the improved curriculum and course design.

The intention to present the two case studies is to introduce the application of the ALT method to manufacturing related courses to benefit student learning. The limitation of this paper is that only the qualitative approach was used to observe the students' performance, but unfortunately no formal and quantitative tests were performed to test any hypothesis. This limitation will be overcome in the STEM research proposal mentioned above to make it more promising. Another drawback is that the instructor could not make statistical comparison between the purely conventional pedagogy and the ALT method due to the small class size. Breaking down the small group would not generate a reasonable sample size. This drawback may be taken care in the future in another way. For example, the instructor may teach the gage R&R by fully using the lecture approach in one semester and by the ALT approach in another semester. The comparison result may further test the effectiveness of this ALT teaching method.

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