Situational teaching based on CMM applied to a mechanical major

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ABSTRACT: Situational teaching based on a customer meets machinist (CMM) model was applied to the course, entitled CNC (computer numerically controlled) Programming and Training for Operation Skills. The aim the model's introduction to the course was to cultivate students' sense of quality, responsibility and their ability to solve actual engineering problems. The course has undergone a comprehensive reform, including situational teaching, an enterprise training environment, program-based training and standardised assessment. It was shown that the reformed course has achieved effective teaching results when compared with more traditional teaching methods.

INTRODUCTION

Customer meets machinist (CMM) originally appeared in the technical documentation for a computer numerically controlled (CNC) lathe in the 40th WorldSkills Competition held in Canada, in 2009. This saying provides much food for thought. It reflects a detailed working situation, and a diverse dialogue about signing and implementing contracts for the processing of mechanical products.

There are a many stories about CMM in practice, one of the best of which is: a customer visited a machinist, taking technical documentation for the processing of a product. The customer was warmly welcomed by the machinist. The machinist carefully examined the technical documentation, while discussing with the customer the technical requirements, quality, price, delivery time, acceptance criteria, packaging and transportation. Finally, they reached an agreement and signed the contract.

Within the timescale of the contract, the machinist prepared the needed cutters, measuring tools, assistance tools; composed the CNC processing program; operated the CNC machining tools; finished the processing of the product according to the requirements; packaged the product, and sent it to the customer. The customer thoroughly examined the product according to the acceptance criteria. If the product met the criteria, the customer would sign the certification. Then, the customer would pay the machinist according to the payment requirements, marking the end of the contract execution.

The situational teaching method aims to design a teaching process that mimics the actual working situation where *customer meets machinist*. The teacher acts as the customer, and the student acts as the machinist. Teachers should urge students to finish the processing of one specially designed product or a batch of them, at a time. The teacher's quantitative evaluations should improve a student's quality and ability.

SITUATIONAL TEACHING BASED ON CMM

Situational teaching based on CMM emphasises the process of work, and the roles of teachers and students in the simulated work environment. The teaching emphasises a training framework that closely combines theory and first-hand practice with a rich, theoretical and practical content [1]. More specifically, features include:

- Situational awareness:

  The teaching process is based upon the practical work situation supported by a full storyboard and a real-life scenario.

- Realistic simulation:

  Situational teaching based on CMM is a simulation of work in a virtual environment, but where the processing and the quality of final products are real. Students have two roles to play: one as machinist, and the other as trainee. Teachers have three roles to play, viz. customer, machinist and teacher. The roles of machinist and customer are virtual and temporary, but the roles of student and teacher are real and permanent.

- Comprehensive:

  There are three aspects of this feature. First, comprehensive teaching content, including CNC machining process design, CNC programming and operation of a CNC machine. Second, the comprehensive training of students. Students' first-hand training will improve their ability to recognise machines and to understand the technology, search for information, carry out negotiations as in the workplace, operate the machine, and enhance their awareness of quality, cost and responsibility.

  Third, comprehensive multi-teaching methods, such as role play, teaching by simulation and project teaching. This combination of teaching methods improves on traditional teaching methods, arouses students' interest and improves teaching efficiency.

- Educational significance:

  Role play is a kind of situational teaching and studying rather than a simple experience [2]. Situational teaching based on CMM is a kind of method or means by which a student's knowledge and ability can be improved. This is the essence of teaching.

- Integration:

  From the start to the end, the classroom is integrated with a training workshop; the teacher is integrated with the client and machinist; and the student is integrated with the machinist. Teachers play the role of teaching, and students play the role, studying. This is an integration of teaching, studying and practising.

- Limitation:

  The CMM is applied to practical training courses related to mechanical subjects as implied by its name. But, the concept could be broadened to include other subjects, such as *customer meets product designer*, *customer meets architect* and *customer meets accountant*.

ELEMENTS OF SITUATIONAL TEACHING BASED ON CMM

The necessary elements for the application of situational teaching based on CMM are:

- Course selection:

  Situational teaching based on CMM, is based on a work process with role play. There needs to be a set of tasks, an operation and quantitative outcomes. Therefore, suitable courses must be operation-based courses in which the operations are the same as, or similar to, the processes of actual work, and where specific work tasks are required. Examples of suitable courses include: CNC Programming, Mole Design and Jig Design.

- Teaching factory:

  The students learn in a factory or workshop environment. This applies to both theory and skills. The teaching factory has the style of a real factory, and should have enough intact and undamaged tools, so as to achieve one person in one position for one machine. The teaching factory should be organised along 6S management lines where the 6Ss refer to sort, stabilise, shine, standardise, sustain and safety.

- Teaching documentation:

  This documentation should cover designing, training, design requirements, products, processing contracts, required technology, preparation bills, processing bills, cutter bills, assistance tools, acceptance standards, check list for acceptance and training report. The documentation will vary by course.

- Teacher roles:

  The teacher has a dual role: that of designer and participant in the teaching, and as technician and tutor for the training.

- Management system:

  A good teaching system needs a well-established management system. This includes management of the workshop, management of the equipment, management of the trainees and management of the evaluation of students' performance.

EXAMPLE OF THE DESIGN OF SITUATIONAL TEACHING BASED ON CMM

Course Characteristics to Apply Situational Teaching based on CMM

The CNC Programming and Training for Operation Skills is a core course for the machine speciality group, which includes CNC technology, mechatronics, manufacturing and automation of machines, design and manufacturing of moulds, computer assisted design and manufacturing, and the application and maintenance of CNC equipment. Students master CNC programming and learn how to operate CNC machines. They learn how to select cutting and grinding parameters and to test for dimensional precision.

Preparation for Teaching

- Restructured training programmes:

  Colleges and enterprises should co-operate to restructure training programmes. By using the alliance platform for vocational training, according to the requirements for skills posed by regional industrial development, schools and enterprises should co-operate to carry out special training programmes. The skills training should feature a dual role, task-driven, step-by-step model, with the necessary knowledge and skills divided across several modules. Each module process is driven by the tasks to be accomplished. The knowledge and skills' training can be tailored from shallow to deep, and from basic skills through professional skills to integrated skills. This implementation process emphasises the dual roles of students and staff, and strengthens students' awareness of quality, cost, innovation and vocational qualities. The process attaches importance to the juxtaposition of the student's profession and industry; the juxtaposition of the teaching process and production process; the juxtaposition of academic and professional certificates; and the juxtaposition of vocational education and lifelong learning [3].

- Teaching documents:

  The teaching documents must be compiled based on actual work. Colleges and enterprises are collaborating to design, optimise, and adjust course structure and content. They are co-ordinating their efforts to develop integrated and professional teaching materials, guidance books for training and typical parts libraries oriented to actual work. There needs to be a change in course assessment methods, with equal importance attached to the results based on intensified vocational training. To improve students' ability to apply English, the series of documentation should be available in English.

- The teaching team:

  The training of the teaching should aim to produce a *high-level talent team*. The teaching team should feature quality teachers with dual roles, a resource pool of part-time teachers and teachers trained in vocational education. Core teachers should be sent to enterprises to attract skilled craftspeople to serve as part-time teachers.

  The teaching team should be able to do both full-time and part-time jobs in enterprises, as part of the collaboration between colleges and enterprises. College-enterprise study, discussion and experience exchanges should continually improve the technology and education at the colleges. An aim is to build a teaching team in which all teachers have the title of *champion of CNC skills* and can provide training and guidance to students. The stress on the establishment of teacher teams is the mantra, *teaching, helping, personal demonstration*. More effort is needed to train young teachers, so as to build a professional teaching team with sufficient numbers.

- The teaching factory:

  Optimise the facilities to build a teaching factory using the machines and equipment of modern enterprises to support the teaching of CNC processing. It should be possible to use existing sites by optimising the design. The teaching factory should implement 6S management. Colour coding can be used to identify areas, and well-established labels and identifications used. The machine tools should be grouped based on type, the tool rooms should be in an adjacent site.

Design of the Teaching Programme

The CNC processing can be divided into CNC turning and CNC milling. The CNC systems include FANUC (Fuji Automatic Numerical Control), Siemens and the *Huazhong Centre Star* system. To give students comprehensive

training, a systematic teaching design for the training of CNC program and operation skills according to the principle of *two stages, multi programs and four steps*, is described below. The teaching programme design is shown in Figure 1.

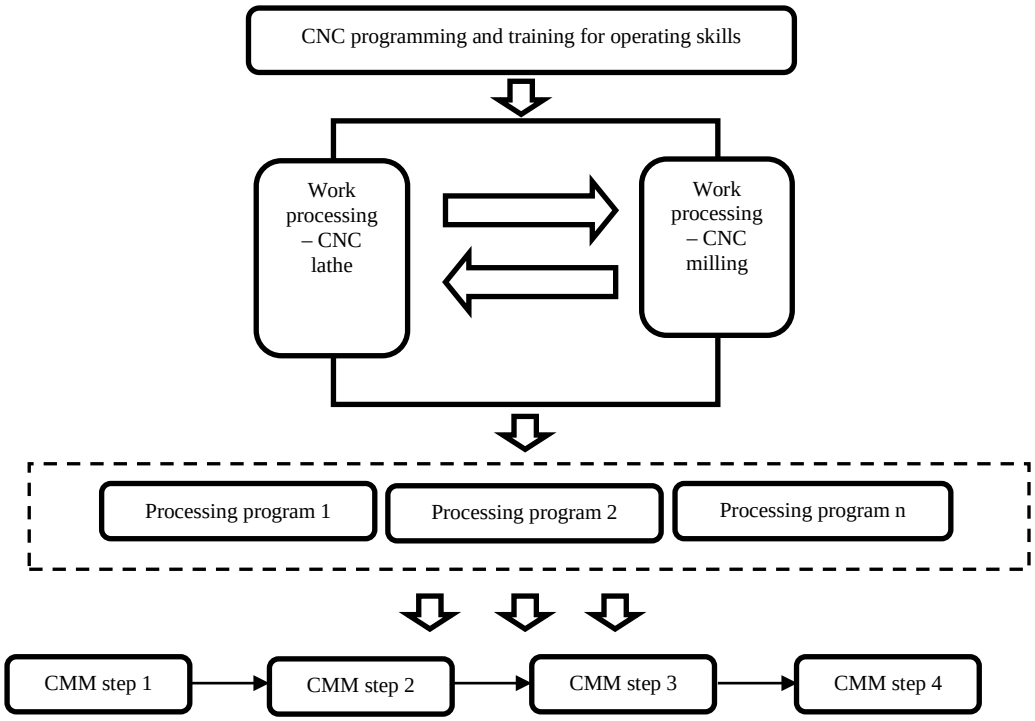

Figure 1: Teaching design for *two stages, multi-programs and four steps*.

- Two stages:

  The CNC Programming and Training For Operating Skills can be divided into CNC lathe processing and CNC milling processing. Each stage requires 7-14 days, based upon the quantity of CNC machines and the class. The stages have no required order.

- Multi programs:

  Three to six processing programs (products) will be set for each stage, based on course criteria, following the principle of from shallow to deep. Each program must have its complete product paper specification and processing requirements.

- Four steps:

  Situational teaching, based on CMM, will be applied to each program. The teaching process is divided into four steps that guide the teacher and student to play the role of customer and machinist, respectively. This teaching process integrates teaching, studying and practice. Table 1 shows the work and study content for each step, for the different roles. The programs run consecutively, until all are completed.

Table 1: The work and study content by role for each step in the teaching.

Step/ Roles	Machinist	Student	Customer (Teacher 1)	CNC processing engineer (Teacher 2)
Step 1	Communicate and negotiate with the customer; ensure the work period, acceptance check criteria, price; sign the contract for product processing.	Study to improve the ability to recognise a picture of machinery, search for information, exchange and communicate, conduct business negotiation and make decision.	Communicate and negotiate with machinist; ensure the work period, acceptance check criteria, price; sign the contract for product processing.	Guide a group of students or one student in special subjects.
Step 2	Compile the operation sheet, CNC processing, preparation bills; take the workblank, cutter,	Study to improve the ability to analyse and find solutions to the problems in process		Check out the operation sheets, CNC processing, preparation bills and evaluate the students'

	gauge, tool and other assistance tools.	design for machine tool, CNC programming, the use of tools and gauges.		performance.
Step 3	Check out the working status of the machine tool, input programming into the machine tool, conduct clamping, conduct processing.	Study to improve the performance in CNC programming, the adjustment of processes, the maintenance of machine tools, tool setting and other independent work; to improve the adaptability to changes.		Conduct the touring guidance and security check.
Step 4	After the processing submit the product to customer.	Study to improve the comprehensive abilities and vocational qualities.	Check and accept the quality of products, execute the contract; evaluate academic performance.	Evaluation of academic performance.

IMPLEMENTATION AND EVALUATION OF SITUATIONAL TEACHING BASED ON CMM

Implementation of situational teaching based on CMM:

- The course:

  Students who are majoring in machinery-related subjects, after completing basic courses and training for beginners, can undertake training for CNC programming and operating skills. The training will be conducted using the two stages, multi programs, four steps design discussed above. The teaching will be arranged on the basis of particular weeks set aside for classes, with three shifts per day, and there will one person at a position for one machine. To implement the integrated teaching programme using situational teaching based on CMM, a task-driven strategy that integrates teaching, studying and practice was adopted.

- The schedule:

  The course of CNC Programming and Training for Operation Skills is set to last for four weeks in two stages. The class is divided into two groups, i.e. one group for CNC lathe training, the other for CNC milling. The two groups exchange roles after two weeks. The training will be conducted, together with the evaluation work using secondary workers. The last day of training is when evaluation occurs. The evaluation is organised by the local department responsible for personnel and social security.

- The teaching:

  Two teachers will be arranged for each teaching class. The teaching management and personal guidance will depend upon the type of CNC processing. The teachers play different roles, viz. one acts as customer and the other as the CNC processing machinist. Teachers play different roles during different phases.

- The evaluation:

  The two main assessment points for students are vocational quality and the processing of products. Assessment contents and principles are given in Table 2. The assessment of each item covers all important technical indicators, including dimensional accuracy, shape accuracy, location accuracy and surface roughness.

Table 2: Evaluation of academic performance of CNC Programming and Training for Operation Skills.

Assessment aspects	Assessment elements	Assessment content	Assessment principles
Vocational qualities (30 points)	Students' integrity (0.3)	1) Student performance on following the rules and regulations in laboratory; 2) Student performance on execution of 6S management; 3) Student attitude towards work; 4) The performance of the machinist role played by the student.	1) If a student violates regulations on operation of machine tools leading to accidents (including personnel accident, equipment accident, damage to cutter and measure), all points for this term will be deducted;
	6S management (0.3)		

			2) Points will be deducted for other conditions.
Processing of products (70 points)	Process design (0.3)	1) Performance on compiling the contract for machinery processing; 2) Performance on preparation bills; 3) Performance on compiling operation sheets; 4) Performance on compiling cutter bills; 5) Performance on compiling the CNC processing program.	1) Grade will be given according to the mark sheet of the programme; 2) Points will be deducted according to how reasonable the process is; 3) Lack of items is not allowed, all points for this item will be deducted if there is no item.
	Processing quality (0.5)	1) Dimensional accuracy; 2) Form accuracy; 3) Positional accuracy; 4) Surface roughness; 5) Other deficiencies.	1) Grade will be given according to the mark sheet of the programme; 2) If one of dimensional accuracy, shape accuracy, location accuracy is out of tolerance, all points for this term will be deducted; 3) Points will be deducted according to how much the roughness is out of tolerance; 4) Points will be deducted for other deficiencies according to the actual condition.
	Operation of machine tool (0.1)	1) Normative operation on machine practice; 2) Accurate clamming work piece; 3) Accurate and skilful use of gauge and tools.	Points will be deducted based on how fluent the operating process is.
	Time to completion (0.1)	The needed time for the completion of products.	Points will be deducted based on how much the processing overruns.

Note: Numerical value in the second column is the weighting coefficient for the element in the first column

Teaching Results

The innovative practice of using situational teaching based on CMM is found to be important. According to the data collected, more than 70 graduates majoring in CNN have become core teachers in secondary vocational schools. They apply teaching theory and methods in the classroom teaching. They train excellent students, who achieve good grades at each level and who are very popular in enterprises.

CONCLUSIONS

Situational teaching based on CMM was applied to the course, CNC Programming and Training for Operation Skills, as an exploration of innovative teaching reform. For this course, good results have been achieved in improving student quality. Situational teaching based on CMM is complex and systematic, requiring specialised hardware and software. This requires an overall and thorough plan.

The most important aspect is training the teachers and building the teaching team. Colleges and enterprises jointly participate using the actual products from enterprises. Qualification standards are those of national vocational skills, and the CNC skills criteria of industry and enterprises. The training was jointly developed by teachers in the college and engineers in the enterprise. The course reform featured situational teaching, an enterprise training environment, program-based training and standardised assessment.

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