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Constructing the graduated prompting assessment learning system for computer-aided manufacturing cutting technique

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ABSTRACT: The purpose of this study is to construct a graduated prompting assessment system for computer-aided manufacturing technology of 2D and 3D cutting techniques for students in vocational schools. A literature review was carried out to develop the materials and assessment system, then, with an expert review, item analyses and reliability and validity tests were performed to modify the system and materials. To confirm the feasibility of the assessment method, a pilot experimental instruction was performed. The findings of the pilot study verified that the graduated prompting assessment system can facilitate students learning about 2D and 3D cutting techniques better than they can with traditional assessments.

INTRODUCTION

Machinery-related departments in vocational schools have been the primary source of advanced mechanical engineering technology manpower for industry over many years. Therefore, it has become the consensus in college mechanical departments to enhance the cultivation of students' practical ability. Furthermore, owing to the rapid development of the computer industry, computer-aided manufacturing (CAM) technology, which is primarily engaged in activities such as cutting path simulation, process design, equipment control, and plan of manufacturing systems [1], has become the mainstream technology in machinery-related industries and widely applied in a range of fields.

Currently, in the process of manufacturing engaged in machinery-related industries, Master CAM software is mostly applied into proceeding computer-aided manufacturing so as to calculate the manufacturing path and plan for cutting tools, to simulate solid cutting, as well as to advance the efficiency and the precision of products. CAM software utilised in industries does not merely consider the technology being able to advance product quality and production efficiency, but also focuses on the integration of enhancing equipment control and operation [2] in the manufacturing process, and establishes the ability of manufacturing complex curved surfaces [3].

In order to realise whether students have actually learned and promoted their ability, instructional assessment has played an important role in educational purposes. Traditional standardised assessments, such as pencil-and-paper tests, focus on the final performance of students after learning, which often ignores the importance of students' thinking process and cognitive structure in the process of learning [4]. For this reason, scholars have proposed the concept of dynamic assessment that emphasises learning, and cognitive presentation in thinking processes, highlights the exchange of a teacher's direct teaching role to become a counselling role in students' learning process, applies positive interaction as tester-medium or feedback of instructions, enhances the promotion of student potentials, changes cognitive functions and structures of students, and promotes students' high-level thinking processes through multiple assessments. Students can, therefore, experience adaptive and overall development in the abilities of potential development, innovation performance, and problem-solving [5].

Nevertheless, the shortcomings of most dynamic assessments lie in not being able to measure students' learning performance as standardised as traditional assessments, so that students' learning performance cannot be measured effectively. The graduated prompting assessment model, offering standardised measuring findings aimed at students' learning process with the prompting system, can progress the shortcomings by giving prompts from abstract to specific, provide assistance scaffolded to learners for constructing personal professional cognition, and lead learners to complete the learning process of technical abilities. Based on the above research motivation, this study aims at constructing a graduated prompting assessment learning system with computer-aided manufacturing of 2D and 3D cutting techniques.

LITERATURE

Dynamic Assessment

Traditional assessments focus on the cognitive structure of intelligence to predict students' future performance with their present test results. Traditional tests were generally pencil-and-paper tests, an assessment giving weights to results, and merely requiring the learning results with segmental knowledge of the students [6]. Compared with general assessments, dynamic assessments (DA) break through the requirements of standardised situations in traditional assessments and change the test situations for comparing individual differences in ability and examining the learning process to find out the strategy of an individual's learning enhancement [7].

Dynamic assessment tends to assess *the maximum level of the presentation of learning potential* of the subjects [8][9]; that is, to develop the situation and condition for assisting or motivating individuals with effective learning and successful behaviour reaction [10], to stress the plasticity of objects, to emphasise the active interference of testers and the interactive cooperation of objects, to evaluate the performance of students at the time, and to carry out the assessment in continuous learning processes [7].

Studies related to dynamic assessment began in the early 1970s and focused on general cognition ability. Until the 1980s, some scholars gradually transferred the studies to the subject field and combined dynamic assessment with subjects for relevant studies [11]. In recent years, there has been even more research aimed at certain teaching practices with computerised instruction or computerised before-and-after methods as the application study of dynamic assessment [12][13].

In the past two decades, studies related to dynamic assessment were classified into learning potential assessment (LPA); the learning potential assessment device (LPAD) tested the limit assessment, graduated prompting assessment, psychometric approach, and a continuum of assessments [10]. This study mainly focuses on the discussion of graduated prompting assessment combined with a computer-aided manufacturing cutting technique course to construct and explore the feasibility of the tool.

Graduated Prompting Assessment

Proposed by Campione and Brown [14], graduated prompting assessment was developed based on the application of the zone of proximal development concept in the sociocultural cognitive development theory of Vygotsky [15]. Jitendra and Kameenui [11] considered that a graduated prompting hierarchy could promote precision in the estimation of individual learning ability, in addition to testing individuals who were exposed to external medium feel instruction sensitivity or response of mediation, which was referred to by Haywood, Tzuriel and Vaught [16], and at the same time, understanding individual learning flexibility and modifiability [17].

In the teaching prompting sequence of graduated prompting assessment, each prompt presents more specific information than the previous one. With graduated prompts, students are provided abstract and general prompts in the beginning, the quantity of prompts depends on the student's ability. If students still cannot comprehend after the first prompt, clearer and more specific prompts will be presented [18], that is, the testers give appropriate assistance and support based on the student's needs and make adjustments according to their learning condition.

RESEARCH DESIGN

Computer-Aided Manufacturing Materials

According to the material for computer-aided manufacturing developed from the project of graduated prompting assessment in the National Science Council by Chen in 2009 [19], four instructional units are classified including 2D graphics, 3D graphics, parameter setting, program editing (post-process) and technical manufacturing operation.

Graduated Prompting Assessment System

The design concept of a graduated prompting system is based on the analyses of test questions to determine misconception and, according to the result of these analyses, gradually enhance the prompts from abstract to practical and clear level. Therefore, according to the analysis of computer-aided manufacturing ability, this study divides the test range into 2D mill cutting and 3D mill cutting; then, with the assessment, as well as the knowledge units and items covered in the instructions, three prompt stages in the system are designed as abstract, half-specific and specific (direct demonstration). Through discussion with the instructors and the professionals in computer-aided manufacturing, the foundation of the prompt modification and system improvement was developed and, finally, the practice situation and answering condition of the tested students were recorded.

The system applies Visual Basic programming and links with Access database. Once the testing student turns on the graduated prompting system, the practice situations, including the listed items for the user, practice time and the condition of using prompts, are instantaneously recorded in the database for further sorting, so that the long-term record is not broken. Some features exist within the program, such as collocating with Master CAM software in a computer-aided manufacturing test, helping students perform to their potential by way of meaningful interaction and feedback instruction, factually recording the practice situation of prompting in students' assessments, and outputting document files with the programming language being convenient for post processing with statistics software.

Figure 1: Log-in.

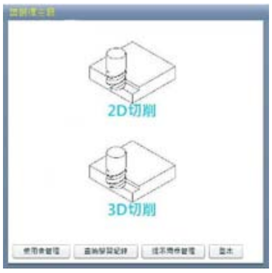


Figure 2: Menu.

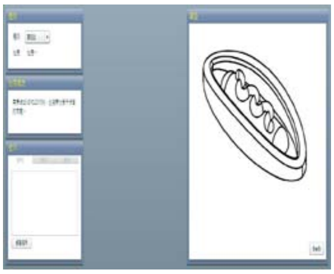


Figure 3: System operation.

Figure 4: Report.

Assessment System Screen

There are four screens in the graduated prompting assessment including log-in, menu, operation and report. System log-in, as the interface for accessing the graduated prompting assessment system, shows the procedures for users to operate the system successfully, as seen in Figure 1. Menu classifies the materials according to the edition of the system materials to assist users' self-learning, as seen in Figure 2. System operation, based on the topic selected, lists all items and the relevant prompts to assist users' learning, as seen in Figure 3. Report displays daily learning situations of the user, as seen in Figure 4.

RESEARCH TOOL AND ANSWERING QUESTIONS

Technical Ability Measurement of Practical Mechanical Manufacturing

In addition to drawing ability, the manufacturing techniques in the measurement contain CNC programming and cutting parameter setting, which are considered the basic elements of test making. The setting of difficulty is reviewed and revised by scholars with the pre-simulation and cutting practiced by a graduate student and three undergraduate students for mill cutting time and its difficulty. The test is finally made with eleven 2D manufacturing technical ability measurements, twelve 3D manufacturing technical ability measurements, and each mill cutting time set to three hours.

Test of Technical Ability Measurement of Practical Mechanical Manufacturing

Technical ability measurement of practical mechanical manufacturing in a computer-aided manufacturing course is divided into two parts, 2D and 3D manufacturing technical abilities. After sorting out the efficient test questions with pre-tests, the acquired data is further tested with item analysis to become the basis for selecting items. The discrimination and reliability are determined by the item analysis from various methods with critical value, correlation analysis, and Kendall's coefficient of concordance. Each item has to conform with the principles of: 1) the relation between each item and the total score reaching significant standard ($p<.05$); 2) the difference between the higher scores (top 27%) and the lower scores (bottom 27%) of independent sample t test reaching significant standard ($p<.05$); 3) according to Kendall's coefficient of concordance, the reliability of evaluators cannot reach a remarkable item level, showing inconsistency and thereby being deleted. Items conforming to the above three conditions remain and become the formal test items; while the ones not conforming to the standard are deleted.

The Item Analysis of 2D Manufacturing

The item analysis of 2D manufacturing aspects is shown in Table 1. The critical value of the first item in 2D technical manufacturing not reaching significance stands for no significant difference between the higher scores and the lower scores, showing the discrimination of distinguishing scores of this item does not exist. Testing 2D manufacturing measurement with correlation analysis, the findings show that the correlation coefficient of each item is significant so that no items are deleted. Regarding concordance test, the Kendall's coefficient of concordance of each item is between 0.747 and 0.900, representing the concordance of evaluators. According to the results of item analysis and reliability test, the first item is deleted; and after the deletion and further item analysis, the correlation between 2D manufacturing measurement and the total score is 0.792.

The Item Analysis of 3D Manufacturing

The item analysis of the 3D manufacturing aspect is shown in Table 2. The critical value of the sixth item of 3D manufacturing not reaching significance stands for no significant difference between the higher scores and the lower scores, showing the discrimination of distinguishing scores did not exist. With correlation analysis, the findings show the correlation coefficient of each item being significant so that no items are deleted. Regarding concordance test, the Kendall's coefficient of concordance of each item is between 0.840 and 0.957, representing the concordance of evaluators. Based on the results of item analysis and the reliability test, the sixth item is deleted; and after the deletion and further item analysis, the correlation between 3D manufacturing measurement and the total score is 0.894. Overall, the correlation coefficient between each item score and the total score is between 0.792 and 0.894, which represents that the relevant distance between each measurement and the overall measurement did not independently exist.

Table 1: 2D manufacturing item analysis.

Topic	Critical Ratio	Value related to total score	Kendall's W	Item analysis result
2D cutting1	2.108	0.527**	0.747***	deleted
2D cutting2	3.074**	0.567**	0.900***	
2D cutting3	4.602***	0.671***	0.889***	
2D cutting4	3.857**	0.504**	0.852***	
2D cutting5	4.621***	0.696***	0.822***	
2D cutting6	2.577*	0.762***	0.789***	
2D cutting7	4.853***	0.698***	0.872***	
2D cutting8	2.777*	0.775***	0.838***	
2D cutting9	2.640*	0.769***	0.860***	
2D cutting10	3.743**	0.788***	0.761***	
2D cutting11	2.319*	0.457*	0.780***	

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

Table 2: 3D manufacturing item analysis.

Topic	Critical Ratio	Value related to total	Kendall's W	Item analysis result
3D cutting1	4.542***	0.796***	0.931***	
3D cutting2	4.527***	0.766***	0.883***	
3D cutting3	3.825***	0.688***	0.859***	
3D cutting4	4.511***	0.784***	0.957***	
3D cutting5	3.213**	0.647***	0.841***	
3D cutting6	1.757	0.546**	0.840***	deleted
3D cutting7	5.689***	0.770***	0.916***	
3D cutting8	5.328***	0.770***	0.890***	
3D cutting9	4.657***	0.655***	0.871***	
3D cutting10	3.102**	0.667***	0.888***	
3D cutting11	2.777*	0.757***	0.871***	
3D cutting12	3.537**	0.708***	0.920***	

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

Answering Questions

2D Cutting Assessment Items

When students are presented with a 2D cutting item as seen in Table 3, the system will show the required picture and test questions for cutting simulation as seen in Figure 5. The circle in Column I shows the mill cutting item that students could possibly have misconceived while gouging this test question. As described in Table 3, the conceptual miss of this cutting item is *how to mill cut cross-shape*. First, students freely simulate cutting with their present cognition; then, when they meet difficulties, click on prompts which show from abstract, half specific, to specific suggestions. As described in Table 3, the abstract prompt of Prompt 1 presents …*Regarding the shape, which function is appropriate?* Half specific prompt of Prompt 2 …*Find out the location of connection and break them down,* and specific prompt of Prompt 3 …*Link the picture elements of cross-shape and apply gouging parameters for mill cutting*. Students do not need to use all of the prompts but decide to continue to the next prompt according to their cognition, so that the prompt number for each student is not necessarily the same. After answering, the system will present the solution as …*Since there are four boxes in a cross-shape, gouging is utilised for mill cutting,* for this test question.

3D Cutting Assessment Items

The concept of 3D cutting items is similar to the concept of 2D cutting items with the difference being that some students are presented different and more mill cutting items. When students are presented a 3D cutting test question as seen in Table 4, the system will show the required 3D item for cutting simulation, as seen in Figure 6. According to Table 4, students have to complete mill cutting items such as interfered face, parallel mill cutting, radial mill cutting, gouging mill cutting, scrap cutting and 3D equidistant finish. Within the items, students could possibly misconceive parallel mill cutting in Column I of Figure 6 with interfered face and gouging mill cutting in Column II. The conceptual miss of these items is …*Need to combine 2D and 3D cutting, and pay attention to interfere face problem*. Similarly, students first freely simulate cutting with their existing cognition, then consider referring to prompts, which are also shown from abstract, half specific, to specific as seen in Table 4, when they meet difficulties. Students choose the use of prompts according to their cognition on the simulated cutting item. If students consider the present prompt is enough for them to complete the cutting, they do not need to use the next prompt. In this case, the prompt number for each student is varied with their cognition. After answering, the system will present the solution for this test question, such as …*First mill cut the top face; then gauge the central part with 2D and cut the setting of curved face and interfere face C with 3D; and finally complete scrap cutting.*

Table 3: 2D cutting item.

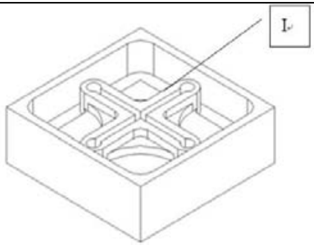
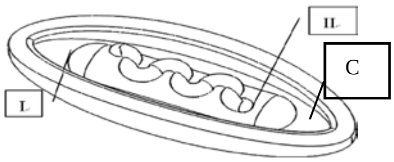
Item / 2D mill cutting	 Figure 5	
	All	I
Contour mill cutting	○	
Gouging	○	○ (island)
Drilling		
Face milling	○	
All-circle path		
Conceptual miss	How to mill cut cross-shape	
Solution	Since there are four boxes in cross-shape, gouging is utilised for mill cutting.	
Prompt 1	Regarding the shape, which function is appropriate?	
Prompt 2	Find out the location of connection and break them down.	
Prompt 3	Link the picture elements of cross-shape and apply gouging parameters for mill cutting.	

Table 4: 3D cutting item.

Item / 3D mill cutting	 Figure 6		
	All	I	II
Interfere face	○		○
Parallel mill cutting	○	○	
Radial mill cutting	○		
Gouging mill cutting	○		○
Scrap cutting	○		
3D equidistant finish	○		
Conceptual miss	Need to combine 2D and 3D cutting, and pay attention to interfere face problem.		
Solution	First mill cut the top face; then gauge the central part with 2D and cut the setting of curved face and interfere face C with 3D; and finally complete scrap cutting.		
Prompt 1	Note the drawing of the top face and mil l cutting method.		
Prompt 2	The head and body of hotdog and sauce are drawn separately, and be careful with the setting of interfere face in the process of mill cutting.		
Prompt 3	Use 2D gauging in the central part, then 3D gauging and scrap cutting.		

FINDINGS

In order to examine the constructed graduated prompting assessment system with computer-aided manufacturing cutting techniques, in comparison with general assessments being more helpful for students' learning, this study decided to simply implement a pilot study. The pilot study analyses if the learning effectiveness of the tested students, who have learned computer-aided manufacturing 2D and 3D cutting techniques, in graduated prompting assessment systems with the interference of abstract, half specific, and specific (direct demonstration) prompts is higher than the performance of the other tested students in general assessments. Forty students from the National Changhua University of Education, Department of Industrial Education and Technology, Mechanical Group, were selected as the subjects and were randomly divided into experimental group and control group for a twelve-week experimental instruction.

According to the analysis findings in Table 5, with the interference of prompts in the graduated prompting assessment system, students' *t*-value in 2D cutting item reached the significance of -2.299 (p<.05), representing that aiming at a computer-aided manufacturing 2D cutting technique course, the learning effectiveness of the tested students in graduated prompting assessments is higher than the other tested students in general assessments, with the average difference being 28.3.

Table 5: Summary of 2D cutting item *t*-test.

Group	Average	Number	SD	*t*
Control	49.7	20	43.72	-2.299*
Experimental	78.0	20	33.30	

*$p<0.05$

Table 6: Summary of 3D cutting item *t*-test.

Group	Average	Number	SD	*t*
Control	47.083	20	24.163	-2.331*
Experimental	64.333	20	22.603	

*$p<0.05$

According to the analysis findings in Table 6, the learning effectiveness in the 3D cutting techniques *t*-test between the control group without using the assessment system and the experimental group with graduated prompting assessment was a *t*-value of -2.331 ($p<.05$), reaching the significance, meaning the learning effectiveness of the tested students in the graduated prompting assessment was higher than the other tested students in general assessments, with the average difference being 17.25.

CONCLUSION AND SUGGESTIONS

The overall reliability of the 2D and 3D technical ability measurements in a computer-aided manufacturing course, designed in this study through item analysis and the inspection of evaluators, is above the acceptable standard. Additionally, having professionals examine and revise the course materials, the materials and measurements in this study were both suitable for graduated prompting assessment systems. Furthermore, aiming at the graduated prompting assessment system in computer-aided manufacturing 2D and 3D courses, this study implemented a Pilot Study with the findings showing that graduated prompting assessment systems, in comparison with general assessments, are more helpful to the enhancement of learning effectiveness in learning computer-aided manufacturing 2D and 3D cutting techniques. Besides, the prompt sequence in the graduated prompting assessment system plays the role of scaffolding the process of students' learning, and assists students in gradually constructing course cognition. In other words, the process of prompting learning in graduated prompting assessments could help train the logical thinking of students. Consequently, this study suggests further research on the possibility of graduated prompting assessments being helpful to the promotion of students' logical thinking ability.

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