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Using an analytic hierarchy process to develop competencies on *mould product creativity* for vocational college students

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ABSTRACT: While product creativity has been extensively investigated, the mould product creativity for vocational college students is unexplored. First, this study collects the status of mould technology in various countries, the scope of technical knowledge of moulds and the relevant literature on creativity performance. In addition, this study involves a quantitative and qualitative content analysis of relevant documents, textbooks and educational objectives of mould performance creativity, which includes originality, practicability, precision, aesthetics and exchangeability in five hierarchies and 16 indexes. Second, this study assesses these criteria by employing the analytic hierarchy process (AHP) technique to solicit opinions from 15 experts by using questionnaires. Results show that *precision*, *exchangeability*, *practicability*, *originality* and *aesthetics* have weights of 34.1%, 28.2%, 23.8%, 8.9%, 4.9%, respectively.

INTRODUCTION

Dies and moulds are one of the typical machine-tool goods that are necessary for modern industries to run mass-production. Mould products are highly customised regarding transportation machinery, electric machinery and equipment, household goods, office goods, optical devices and equipment, construction materials and equipment, toys and sundries [1]. That is, moulds are widely used throughout the manufacturing industry, from the simplest daily commodities to high-precision electronic components. Therefore, the mould industry is critical to the development of manufacturing in a country and a significant element in modern manufacturing. The primary cause of unbalanced supply and demand comes from the gap between the number of personnel produced by academia and the demands of industry. As a result, to cope with industrial demand, the educational system must switch from courses emphasising academic theories to courses focusing on the combination of theoretical foundations and professional technical abilities.

Technical creation is not only the ability to manufacture; it involves research and development, as well. It also includes product design, production methods, planning, organising and executing innovative activities for an enterprise's technical system. The competencies that students need can then be converted to observable data using competence indicators that reflect their learning performance. A competence indicator is a type of competence-oriented curricular goal. It refers to content and abilities that students should have. As a result, the transformation of curriculum to include competence indicators has become a crucial and mandatory foundation stone in current technical and vocational education.

To reconsider the professional practical abilities required by students and the mould personnel demand of industry, it is imperative to plan a curriculum for mould design and analysis. Steuer and Na [2] revealed there were about 18 articles on the AHP combined with finance, whereas Vaidya and Kumar [3] found there were 150 articles using the AHP for general applications. Besides applying to the finance sector, the AHP was adopted in education, engineering, government, industry, management, manufacturing, personal, political, social, and sports [4]. The analytic hierarchy process aims to systematise complex problems. The AHP can be applied to a curriculum emphasising practical mould creative abilities to delaminate the phases. It is then possible to use a hierarchy to separate it into different hierarchies. This structuralisation can help curriculum planners to analyse the complexity of a curriculum when dealing with complicated and divergent curriculum requirements [5].

LITERATURE REVIEW

Creativity

Creativity is a topic of increasing interest, given its importance and applicability to every field [6]. Creativity originates from *creates* in Latin, and means to grow, make or produce. Since Guilford proposed the significance of creativity at the Analytic Hierarchy Process (APA) Annual Meeting in 1950, studies on creativity have appeared in various academic fields. In recent years, many scholars have organised and analysed studies pertaining to creativity. Both Gardner [7] and Sternberg and Lubart [8] proposed interdisciplinary viewpoints and a confluence approach. In *A Dictionary of English Language* in 1988, the word *creativity* was formed by educationists through many years' research and experience.

Creativity is defined as the ability to transcend traditional ideas, rules, patterns, relationships or the like, and to create meaningful new ideas, forms, methods, interpretations. Creativity refers to the production of novel and appropriate ideas and products, that is to say, novelty and appropriateness is considered to be two essential dimensions of creativity [9-13]. Amabile stated that creativity is a property of products and developed a tool for the assessment of product creativity [14]. Dass defined creativity as the organisation or reorganisation of each element to reach new or efficient production processes [15].

Creativity can be as large as a long-term endeavour or achieving a dream, or as small as wisdom in daily life. No matter when and where, it can be operated and presented effectively. In psychology, it is common to define creativity in reference to the four main areas, namely the creative *process, product (output), person and the creative environment* [16-18].

Moreover, in the domain of engineering design, leading researchers categorise design into broadly similar sections using the terms: design *problem, process, types (output), activity and organisation/team/personnel* [19-23]. Besemer proposed the three factor-model composed of novelty, resolution and elaboration, and synthesis dimensions for understanding product creativity for three designed chairs [24].

Dorst and Cross evaluated designs on overall quality and creativity aspects [25]. Kreitler and Casakin focused on the evaluation of the creativity of the designs by four expert architects, and there were 15 variables referring to different aspects of the process and outcome of creative design [26]. The basic variables refer to creativity features of the designs, and constitute the core of creativity evaluation in their study. It was first defined by Guilford (and others) and includes the four classical factors of creativity, namely fluency, flexibility, elaboration and originality [27]. In addition, the study by Walumbwa, Hartnell and Oke determined the items that can be evaluated as the components of creativity in the design process [28].

Assessment of the product was done according to the characteristics of creativity, which are value, appropriateness, flexibility, fluency, novelty, originality, elaboration, redefinition, ability to answer needs and open-endedness (evolution). In summary, the research reported here makes use of the above research categories, and the mould product evaluation criteria, which include originality, practicability, elaboration, aesthetics and flexibility. Originality involves a product that has the characteristic of an idea that is new, unusual, fresh, genuine and precedes the other products. Practicability is the ability to manufacture popularly or to have an application to humans' lives. Elaboration refers to a product designed with given attention to details. Aesthetics often is taken as meaning the appearance or styling in the field of product manufacturing. Flexibility shows that the product is being responsive to change and a set of products that very economically and quickly and effectively can adapt to changing circumstances.

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), developed by Satty in 1971, is an analytic logic that combines inductive and deductive methods. It is an effective decision-making method that reflects the process of decomposition, judgment, and the synthesis of decisive thinking in humans. The AHP primarily is utilised in the multiple-goal decision-making method. The AHP method maps complicated decision problems to a hierarchical diagram. With the resulting criteria hierarchy structure, eigenvectors can be calculated using a matrix of pair comparison of each criterion by a nominal scale. It can be used to represent and calculate the weights of each criterion in certain hierarchies and then organise them, creating a reference for decision analysis. The steps of analysis are as follows: 1) Describe and analyse the problem; 2) Determine structural hierarchical relationships; 3) Design and collect questionnaires; 4) Build a pairwise comparison matrix; 5) Calculate the maximal eigenvector of A (λmax) and the eigenvector (Wi); and 6) Perform a consistency test.

PROCEDURE

Establish a Hierarchical Relational Framework

Researchers must carefully identify their research problems. The Delphi method was applied to define the evaluation criteria and sub-criteria. Murry and Hammons suggested that the Delphi method should summarise expert opinions on a range from 10 to 30 [29]. Therefore, an initial questionnaire was distributed to 15 experts. This questionnaire included five criteria and 16 sub-criteria. A hierarchy framework was then established, containing the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives. According to research by Saaty [30], it is inappropriate to have more than seven elements in one hierarchy. This is because inconsistency can occur easily in the evaluation process when there are more than seven elements. This in turn affects the weight of each element and further influences decision making.

Form the Pairwise Comparison Matrix between Levels

Next, in this study, a comparison matrix was developed by comparing pairs of criteria or alternatives. This pairwise comparison helps experts independently judge the contribution of each criterion to the objective. Following Saaty, the researcher assigned a single number drawn from the fundamental 1-9 scale of absolute numbers shown in Table 1 [31]. Pairwise comparison generally refers to any process of comparing entities in pairs to judge, which of each pair is preferred or has a greater amount of some quantitative property.

Table 1: The pairwise comparison scale.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	

Check the Consistency of the Judgments

In this step calculations were performed to find the maximum eigenvalue, consistency index (CI), consistency ratio (CR) and normalised values for each alternative. The consistency test aims to eliminate possible inconsistencies revealed in the criteria weights by computing the consistency level of each matrix, and is one of the essential features of the AHP method. The CR determines and justifies the inconsistency in the pairwise comparisons made by the respondents in this study. If the CR is less than 10%, it is considered adequate to interpret the results [32].

Establish Global Priorities

After the consistency test, the local priority can be converted to a global priority via additive weighting. This step calculates the relative weight of each alternative to the overall problem or system. A final decision maker can use this information as a reference when making decisions. The final step is to establish the normalised priority weights of the curriculum to identify the best alternative. These weights can be determined by first laying out the local priorities of the curriculum, with respect to each criterion in a matrix and, then, multiplying each column of vectors by the priority of the corresponding criterion. Finally, the results in each row are added to calculate the global priorities of the curriculum.

RESULTS

The AHP approach adopted in this study was used to evaluate the contrast of the perceived selection criteria. A survey questionnaire was conducted to investigate the relative importance of the mould performance creativity curriculum for industrial-oriented technical and vocational college students. The criteria and their measurement items initially were developed based on a literature review of the status of mould technology in various countries; the scope of technical knowledge regarding moulds; and creativity capability.

In this study, data were analysed using Expert Choice, an application implementing the analytic hierarchy process. The five evaluation criteria at the first level include precision, exchangeability, practicability, originality and aesthetics. The following sub-section describes the characteristics of the sub-criteria. The findings of this study suggested that the criteria are all comparable, and none of them can be sacrificed. Table 2 shows that, identified in this study, were some interesting findings on the importance of mould performance creativity curriculum.

According to 15 local mould experts, precision (0.341) had the highest weight in mould performance creativity curriculum, followed by exchangeability (0.282), practicability (0.238), originality (0.089) and aesthetics (0.049). For the main criterion, press mould and plastic mould design had the highest weight of 0.678, followed by product and mould design perception (0.562), and interior mould assembly and disassembly (0.440).

In addition, engineering economics had the lowest weight of 0.083. For the main sub-criterion, respondents reported that the CNC milling machining programme route (0.857) was the prime value for mould performance creativity curriculum, followed by the mould optimisation (0.793) and model rebuild technology (0.631). Finally, fatigue experiment analysis had the lowest weight of 0.014.

Table 2: Relative priorities of the selection criteria of the mould performance creativity curriculum.

Mould performance creativity curriculum	Priority	Main Criterion	Priority	Sub-Criterion	Priority
Precision	0.341	Data Processing Technology	0.410	product precision scheme	0.499
				mould measurement control	0.501
		Materials Engineering Test	0.292	mechanical metallurgy and test	0.242
Precision	0.341	Materials Engineering Test	0.292	material damage analysis	0.172
				dislocation plastic deformation	0.162
				hardness experiment analysis	0.151
				mould or product external stress remains	0.135
				corrosion and material damage	0.105
				tensile experiments analysis	0.019
				fatigue experiment analysis	0.014
		Plastic mould structure	0.298	mould cooling design	0.156
				injection plastic pressure	0.156
				runner design and runner balance	0.144
				dissolve plastics wave front area and velocity	0.141
				infilling patterns	0.139
				gate design	0.136
				contracts and buckling	0.129
Exchangeability	0.282	Interior mould assembly and disassembly	0.440	parts standardisation	0.333
				material general standardisation	0.333
				rapid assemble and disassemble mechanism simplify	0.333
		CAD/CAM software	0.319	design drawing date transformation	0.250
				each set of software	0.250
				simulate machining identical	0.250
				drawing simulate and parameter setup	0.250
		Mould material standardisation select	0.241	material recovery use	0.769
				manufacture measure and material consideration	0.231
Practicability	0.238	CNC turning and milling operate	0.313	machining concept	0.452
				procedure decide	0.31
				bit tool select	0.238
		Sample development	0.219	model rebuild technology	0.631
				rapid prototyping	0.369
Practicability	0.238	Workpiece	0.193	grip structure simplify	0.372
				hold, grip and workpiece fixed principle	0.334
				drilling, jig and fixture modality	0.294
		Special machining ability	0.192	electrical discharge machining	0.281
				wire electrical discharge	0.281
				abrasive machining technology	0.28
Practicability	0.238	Special machining ability	0.192	ultrasonic machining technology	0.084
				laser machining technology	0.049
				water cutting machining technology	0.026
		Engineering economics	0.083	mould making cost	0.536
				produce process cost	0.247
				whole consume material cost	0.217

Originality	0.089	Press mould and plastic mould design	0.678	product create	0.207
				mould optimisation	0.793
		Produce basic concept	0.169	CNC milling machining programme route	0.857
				CNC turning programme route	0.143
		Mould basic function and make	0.153	make process	0.34
				mould properties and life calculation	0.247
				mould mechanism design	0.246
				mould engineering introduction	0.167
Aesthetics	0.049	Product and mould design perception	0.562	colour visual design	0.416
				green transmit design	0.403
				3D modelling and blending	0.181
		Product packing design	0.438	packing material select	0.499
				green packing design	0.268
				packing structure design	0.234

CONCLUSIONS

Although the priority of the mould performance creativity curriculum was thoroughly investigated in this study, the limitations should be addressed in future studies. First, the mould performance creativity curricula of the five domains used in this study might not represent all domains. Second, this study was conducted with relatively small samples, especially of the mould experts. This may have caused a sample selection bias problem. This study applied the AHP approach, and found it useful for a complicated mould performance creativity curriculum problem. The analytic hierarchy process can be applied to future studies on various multi-criteria curriculum planning problems in educational areas. However, the interrelationships among the selection criteria in this study remained undetermined.

Future research should examine these criteria using the analytic network process (ANP). For example, the correlation between *press mould and plastic mould design* and *CNC milling machining programme route* and their effects on the selection of mould performance creativity curriculum could be analysed. The relationship between these criteria may affect the extent to which a better mould performance creativity curriculum can be planned for industrial-oriented technical and vocational college students. In conclusion, planning the mould performance creativity curriculum is a challenging issue, but should be pursued to advance the mould curriculum in vocational education.

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