



Factors in an Interdisciplinary Curriculum for the Students of Industrial Design Designing Multifunctional Products

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To assist learners in obtaining professional abilities, meet social demand for talent, and achieve favorable educational outcomes, academic courses generally have unique syllabuses, learning goals, and teaching purposes according to their characteristics and specialized knowledge and skills. Furthermore, it could help the students of Industrial Design enhance the connection with employment after the graduation when they understand the characteristics of auxiliary devices and equipment before entering workplaces. Meanwhile, the students being cultivated the design capability could improve and innovate tools, as the improvement of auxiliary devices and the practical design of innovative products and the functions from a professional engineer are close to the users' demands. In this study, the Delphi method, a group decision-making technique, and the analytic hierarchy process (AHP) multiattribute decision-making function was adopted to establish a decision-making model for designing multifunctional products for assessing the students of Industrial Design in learning effectiveness in innovative engineering product design and development. In addition, a practical multifunctional product-design case was investigated to demonstrate the application of the model. This study found that integrating interdisciplinary courses and instruction by industry professionals and introducing industry-academia cooperation had a considerable influence on interdisciplinary teaching and learning.

Keywords: Delphi method; analytic hierarchy process; interdisciplinary; learning effectiveness

INTRODUCTION

In the 1980s, the Formosa Plastics Group in Taiwan provided 3-month interdisciplinary professional training for newly graduated employees working in various departments. After completing the training, those who did not pass a written examination were not offered a position of employment. Managers were required to possess an understanding of the chemical engineering processes implemented at various plants, relevant chemical formulas, and electromechanical maintenance operations in control rooms. Similarly, chemical and electromechanical engineers

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were required to demonstrate professional knowledge in other departments during the training.

The private chemical engineering enterprise provided 3-month compulsory and intensive training to business management graduates to assist them in understanding chemical engineering processes and electromechanical operations as a form of interdisciplinary professional training. This type of training is typically difficult for schools to offer, and students tend to be reluctant to follow the training. However, enterprises typically require newly graduated employees to undergo this type of training to foster corporate knowledge and ensure corporate competitiveness.

Recently, technical and vocational colleges in Taiwan have focused on interdisciplinary learning and employing professional technicians as teachers. However, this learning model is less innovative than the training model for newly graduated employees adopted by the Formosa Plastics Group in the 1980s. The low employment rate of university graduates in Taiwan and the irrelevance between field of employment and academic background prompted educational reform. During the reform, interdisciplinary learning was introduced to integrate practical training and classroom learning to assist students in obtaining employment following graduation. In addition, interdisciplinary courses and instruction by professional technicians became crucial strategies for improving technical and vocational colleges. Furthermore, they are crucial indicators for assessing the teaching effectiveness of such colleges with the aim of fostering practical and professional abilities, and to develop the personal traits of students to enhance their future workplace competitiveness.

In recent years, the Ministry of Education in Taiwan has not only promoted interdisciplinary research and learning, but has also encouraged colleges and universities to employ professional technicians as part-time teachers. Furthermore, the Ministry of Education has encouraged universities and graduate schools to cooperate with industries and by subsidizing credited courses for offering relevant 2-year programs. Students who successfully complete the program receive a Credit Certificate. In addition to subsidizing such programs, the Department of Education also subsidizes master's programs to enhance industrial technology and foster talent. Upon graduation, in addition to granting students a master's diploma, graduate schools are required to achieve an employment rate of 70%. Because these programs are highly specialized, the Department of Education requires the graduate schools to sign a cooperation agreement with related enterprises about

State of the literature

- In order to improve the employment opportunities for the students in technology universities, Ministry of Education has focused curriculum planning on the team teaching of interdisciplinary learning and professional technicians in industries; meanwhile, the industry-university collaboration projects are introduced into the syllabi for an important evaluation item to promote the teaching quality.
- Interdisciplinary learning is regarded as an innovative curriculum for the students of Industrial Design.
- Interdisciplinary curricula could help enhance the practical application and the design capability of the students of Industrial Design.

Contribution of this paper to the literature

- By discussing the factors in interdisciplinary curricula through Delphi method and AHP as well as combining the design cases of multifunctional products, this study intends to explain the reliability of interdisciplinary curriculum planning and to help enhance the practical effect of the curriculum planning.
- This research case is an industry-university collaboration project to first complete the product development and the patent application, then to be awarded in international contests and to proceed the mass production of the product, and finally to introduce the key success factors in the curriculum planning. It could help cultivate the students' practical experiences as well as provide the reference for relevant new curriculum planning.
- Since the lifecycle of technology products is shortening and the requirements for the appearance aesthetics and the multiple functions of products are getting strict, interdisciplinary curricula could help expand students' knowledge. Besides, the team design could assist students in enhancing the employment opportunities.

employment, practical training, instruments and equipment support, product development, international competition, and research. Previously, the credited courses offered in master's programs focusing on the technology industry were in the initial planning stage; currently, credited courses and master's programs are in the design and management stage. Whether these specialized programs are approved and subsidized by the Department of Education is based on the following factors: course content design (i.e., relative to industrial requirements), whether a team-teaching approach involving qualified teachers and professional technicians is employed, whether interdisciplinary practical training is provided, and the employment rate following graduation is satisfactory. These measures were introduced to ensure effective practical learning and to enhance the employment competitiveness of new graduates.

From the perspective of interdisciplinary education, this study examined how design courses for improving auxiliary equipment or product can be introduced to architecture and interior design students to promote the practical effectiveness of auxiliary study tools. Moreover, because sketching, hand drafting, 3D illustration, and basic aesthetics courses are required courses for these students, such design courses facilitate introducing other interdisciplinary courses such as product design. Furthermore, these students must also emphasize environmental design and the related competitions (Al-Marzouqi, and El-Naas, 2012) as well as focus on the development of engineering sustainable construction materials (Mihelcic et al., 2007). The findings of this study show that when developing new products, enterprises focus on product innovation, creativity, appearance, functionality, and patent competitiveness. Therefore, to achieve the course objectives of product design education, an interdisciplinary approach must be introduced to enhance the practical design ability of students, meet the requirements of enterprises, and improve the employment rate of graduates. Integrating student learning in new product design and development with interdisciplinary courses assists students in understanding the importance of intellectual property in new product development, how to integrate product aesthetics and new technology, and how to consider customer preferences and market share. In addition, course design, teacher certification, and funding must be considered to enhance the effectiveness of interdisciplinary learning.

The relationship between interdisciplinary curricula and design practices

Rapid improvements in technology have markedly shortened the lifecycle of technology products, increased demand for quality products, and enhanced product competitiveness and attrition. Education can promote technology innovation and improvement, and therefore education on teaching methods and course design must be innovative in leading social change, generating corporate knowledge, and cultivating talent. Currently, product aesthetics is the main market appeal of fashion goods; in addition, multifunctional and high-tech products have become cultural symbols indicating style and status. Accordingly, education in product design must adequately equip students with a multiple abilities related to product design to ensure that graduates meet the talent demands of enterprises and can develop innovative products that are competitive in the market. Therefore, developing interdisciplinary courses and educational strategies is essential for education in product design.

Designers should understand user preferences to develop products with appealing affordance features. According to Xenakis and Arnellosb, designers provide a means for people to interact with their environment through an object. Concurrently, effective design is aimed at communicating the meaning of an

object to the user(Xenakisa and Arnellosb, 2013). The dimensions and functions of a product that elicit an aesthetic response from users should be determined at the product planning stage. This assertion is evident in several contemporary studies that have highlighted the importance of aesthetic perception, aesthetic cognition, and aesthetic responses(Noble, &Kumar, 2012; Carbon, 2011; Blijlevens et al., 2012). Because aesthetic perception is a multidimensional phenomenon involving several aspects of cognition and action(Leder et al., 2004), designers must understand consumer responses and various determinants of product form(Crilly et al., 2009) from the perceptive of users. At the product design and planning stage, product affordance features and interaction aesthetics should be considered(Xenakisa & Arnellosb, 2013). Particularly at the stage of product planning, product modernization and technology integration are crucial for enhancing product competitiveness in commercial markets.

Because humans are influenced by their environment, education in product design must be integrated with living habits to produce interaction and affordances among designers, products, and users and to reduce the risk and uncertainty involved in decision-making process related to design (Heilman et al., 2010). To understand interdisciplinary learning in product design, this study focused on assisting students in formulating a design concept. Throughout the process of designing products, product innovativeness, characteristics, and functionality must be considered in addition to product commercialization and marketing, production costs, manufacturing technologies, and future developments in order to assist students in understanding that effective product design should be aimed at satisfying consumer needs. Friedman addressed three crucial perspectives in theory construction in design research, namely criteria, approaches, and methods(Friedman, 2003). To explore the factors that affect the interdisciplinary studies of architecture and interior design students in product design, an evaluation model was created through literature reviews and the application of the Delphi method and analytic hierarchy process (AHP). The model provides criteria for product design and a reference for developing interdisciplinary courses. Figure 1 illustrates the overall research framework, in which the Delphi process was used to generate critical criteria for establishing the AHP model through expert assistance.

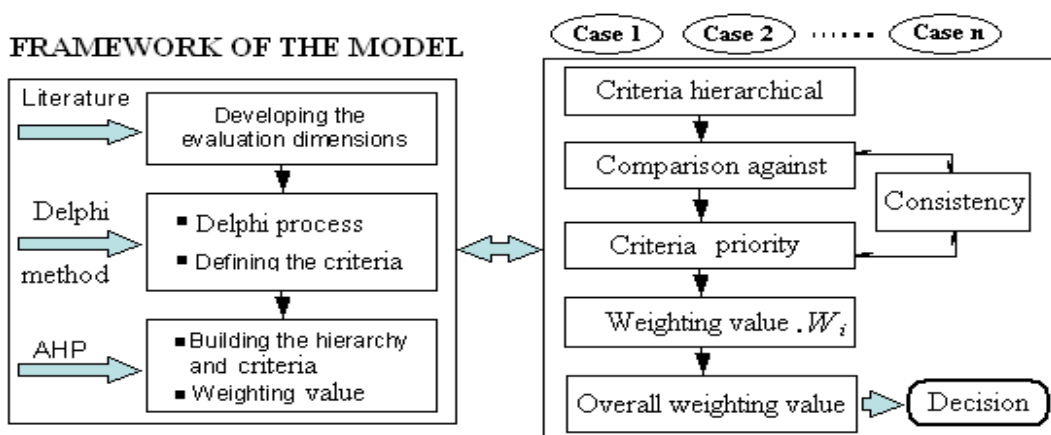


Figure1. The overall research framework

Understanding product design

Designers must possess a comprehensive understanding of the environmental factors influencing the design of new products in order to meet user expectations and reduce the risk of making wrong decisions when developing new products. Therefore, appropriate design decisions are crucial during product development and design. In addition, aesthetic perception, functional design, and new technologies must be considered.

Cognitive framework for design decisions

In various departments, senior managers, senior designers, and product designers are responsible for making design decisions. A decision-making team must first possess a profound understanding of market competition, user preferences, and the environment to predict new product attributes and market demands. Such predictions serve as a reference for making decisions.

The experiences and abilities of decision-making teams and their understanding of user preferences facilitate making effective decisions. Although predictions may differ from reality, by understanding market trends and user preferences, designers can make decisions that are more likely to conform to user preferences and facilitate achieving predicted goals.

Rapid technological progress invariably shortens the lifecycle of products. For example, the lifecycle of smart phones is approximately 1 year for functionality and technological attributes and 2 years for appearance; moreover, the lifecycle of smart phones is anticipated to be further reduced. In the highly competitive environments, decision-making and design teams play an extremely crucial role in corporate sustainability. Therefore, design teams must consider the factors of design uncertainty throughout the design process. When developing new products, an assessment method must be established to manage and reduce design uncertainty. Workplace training not only fosters a positive attitude toward lifelong learning and enhances the knowledge and abilities of designers, but it also assists designers and enterprises in accumulating knowledge capital and reducing uncertainty when making design decisions.

Cognitive framework for aesthetic perception

During the practical applications of aesthetic perception in the overall industry, aesthetics perception has been verified to demonstrate significant influence on corporate image as well as product development and design (Hassenzahl, & Monk, 2010). Therefore, in recent years, the Ministry of Education has actively promoted aesthetic perception in general courses from elementary school to senior high school in order to assist students in understanding aesthetics. The Ministry of Education trained seed teachers in preparation for teaching general courses on aesthetic perception. When industry experience is transformed into corporate knowledge, education authorities should endeavor to develop means for applying corporate knowledge into new applications. Various businesses consider aesthetic perception when designing products in order to enhance product competitiveness and market appeal. In addition, integrating product design and aesthetic perception has become a cultural symbol for style. Understanding aesthetics is fundamental to making design decisions and essential to successful product development (Hassenzahl, 2004).

Aesthetic perception is often considered an abstract and ambiguous concept in product design, and such perceptions are often difficult to express verbally.

Therefore, making design decisions often generates feelings of uncertainty. Aesthetics entails more than simply interpreting how attractive or plain a product is; for example, it can be used to express fun, trust, and attraction (Park et al., 2004). Understanding aesthetic perception is extremely crucial in product design. The level of understanding that designers possess on aesthetic perception is related to the amount of experience and knowledge they have accumulated; thus, experienced designers are skillful in applying aesthetic perception. In addition, affordance-based design methods (Maier, & Fadel, 2009) often form the basis of discussion related to the practical and innovative aspects of design. Aesthetic perception and product functionality can enhance product appeal. Evaluating product competitiveness involves assessing aesthetic perception and product functionality because they affect both production costs and sales prices.

Courses on freehand sketching, sketching in 3D, and designing color schemes provide a basis for applying aesthetic perception to designing products and fostering creativity. Freehand sketching is a crucial skill in the field of design. In addition, sketching in 3D and understanding the principles of color design are essential skills for visually presenting product samples. Masry et al. indicated that incorporating freehand sketching into computer aided design applications can facilitate transforming 2D sketches into 3D objects (Masry et al., 2005; McCrae, & Singh, 2009).

Cognitive for functional design

The functional design of products can be understood by reviewing theories related to human factor engineering. Human factor engineering explains how human-product interactions achieve an optimal state as well as the purpose of cognitive ergonomics. Examining the physical phenomena associated with a product from the perspective of human factor engineering enables designers to infer which physical characteristics should be considered during the initial design stage in order to improve product safety and comfort and ensure that products facilitate rational human-product interactions. Human factor engineering is related to the physical characteristics of human-product interactions and is core course for students learning product design. Currently, new technologies are innovated to produce multifunctional products, and the diversity of new products further stimulates technological advancement. In highly competitive markets, many products often have similar functions, although consumers often do not understand how to use some technological functions or might not even know that such functions exist before they become obsolete.

Consumer markets are characterized by new technologies and multifunctional products; however, many people consider some product functions difficult to use. Therefore, designers should exercise creativity in simplifying the user interface and providing comprehensive instructions on using multifunctional technological products. The human senses play a critical role in how people understand and experience products (Dagman et al., 2010). Affordance refers to how animals respond to and interact with objects or their environment according to their visual, auditory, olfactory, gustatory, and tactile perception. If designers understand the role of affordance features in user-product interactions, then they are more able to design multifunctional technological products according to user requirements. In addition, when considering which affordance features to incorporate into a product, designers should avoid features that project ambiguity and uncertainty.

Subsequently, designers should consider the perspective of universal design, which refers to designing products that can be used by anyone. Thus, designers must understand user-product interactions, theoretical models related to human psychology and behavior, and various context-specific factors. During the design

process, products must elicit an emotional response and demonstrate usefulness and usability. After considering these factors, this study proposed a cognitive for designing multifunctional technological products (Figure 2).

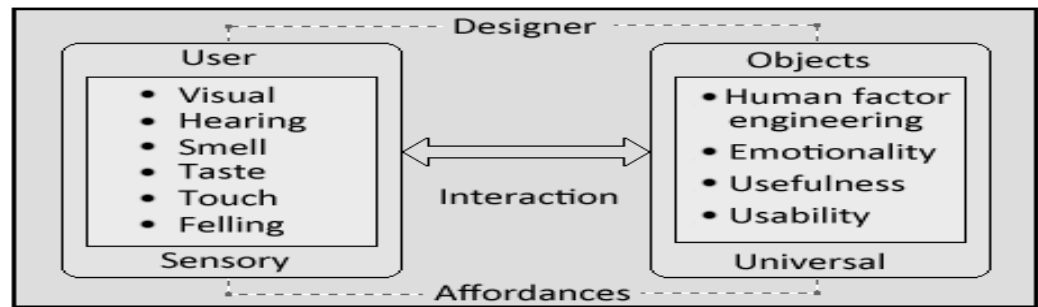


Figure 2. Cognitive scheme for designing multifunctional technological products.

Cognitive framework for science and technology

Recent studies on product design have focused on the role of aesthetic perception, fashion, and style in satisfying the materialistic desires of consumers. In addition, advanced technologies have been incorporated into the design of multifunctional products. Currently, products with specialized functions have entered into a competitive and disciplinary era. Design teams must possess skills from multiple disciplines to develop and design new technological products. In highly competitive environments, product imitation has increased the availability of products with similar functions, and new products continue to be developed, shortening the lifecycle of products. To rapidly develop and design new products, interdisciplinary team members must cooperate closely with each another, and specialists must possess adequate understanding of the work tasks performed in other departments in order to maximize the benefits of interdepartmental cooperation at various stages of the design process, and to avoid problems involving interface design and fabrication, particularly those pertaining to the dimensions interface quality and objective/measurable features (Dagman et al., 2010).

Collaboration research has focused on what makes collaboration productive, including group membership and forms of participation (Ryu & Sandoval, 2015). According to Gnaur et al., interdisciplinary learning and cooperation are crucial in education, particularly when fostering collaborative skills in interdisciplinary learning contexts (Gnaur et al., 2015). The collaborative design of new technological products can enhance product competitiveness (Daniels et al., 2015). Multidisciplinary design teams are less likely to encounter conflicting opinions and tend to be more efficient in communicating, thereby mitigating the departmental selfishness of specialists. In addition to applying the principles of form follows function and function follows form, designers should also consider production costs and potential difficulties involved in manufacturing and processing. During product design and development, analyzing the relationship between products and production systems is also crucial (Maffei et al., 2014).

Given the rapid advancement of technologies, interdisciplinary learning is a crucial factor that has a positive effect on integrating student learning and industries. Focusing on learning strategies is essential to creating an integrated and interdisciplinary perspective for sustainability education. Active learning strategies based on methods that accommodate conceptually and practically diverse data as well as divergent epistemologies are needed (McLaughlan, 2007).

RESEARCH METHODS AND DESIGN

This study explored the criteria related to interdisciplinary design and then employed the AHP multiattribute decision-making model function to establish a hierarchical framework for each criterion, which could help discuss Multiple Goal Orientation on Learning Motivation and Learning Behaviors(Li & Shieh, 2016). Subsequently, an AHP questionnaire was designed and administered, the results of which were used to obtain the relative weighting value (WV) of each criterion. The results may serve as a reference for course designers.

Delphi method

The Delphi method, a multiattribute research approach that involves expert assistance, was first applied by the Research and Development Corporation in 1946 to predict its future development. Because the Delphi method improves decision-making, it has been prevalently employed in various domains including academic research. For example, Shyr and Lo adopted the Delphi technique and revealed the practical competency requirements for students in a technology university program (Shyr, &Lo, 2012). The present study invited four senior architects (one of whom has been the president of an architect union), three senior interior designers (two of whom have been presidents of interior designer unions), four chief executive officers in the product design industry, and four senior university professors, all of whom possess a minimum of 15 years of work experience. The criteria that fulfill the requirements of this study were determined after the 6-month Delphi process was completed and are described in the following section.

Analytic Hierarchy Process (AHP)

Since Saaty first introduced the AHP in 1971, it has been widely applied in decision-making analyses in various business and academic areas. AHP is a multiattribute decision-making analysis technique that can facilitate selecting the optimal decision-making solution related to management and can assist in understanding the relative WV of each criterion. The AHP is a quantified qualitative decision-making model (Hsueh et al., 2013) that can be employed to analyze the advantages and disadvantages of a single solution or to select the relative optimal solution among multiple possible solutions. Studies that have applied the AHP to education have investigated the factors involved in cultivating student learning motivation(Shieh et al., 2014), evaluating the quality of personalized learning scenarios (Kurilovas,&Zilinskiene, 2012), designing socially relevant computing systems aimed at inspiring social change (Cardenas, 2011), and determining which key capabilities are essential for firms(Hafeez et al., 2002).The strengths of the AHP are listed as follows:

- (1) Applicability: The AHP is a qualitative and quantitative decision-making model that can be applied in various areas and can reduce the risk of decision errors.
- (2) Adaptive: AHP assessment results are clear and can be maintained and modified in the future; therefore, the effectiveness of decision-making can be enhanced.
- (3) Usability: The calculation process is easy for decision makers to understand, analyze, and apply.

The steps for establishing an AHP assessment model are as follows:

- (1) Define the assessment items and analyze the related criteria.
- (2) Define the hierarchy of main criteria and subcriteria.
- (3) Design and administer AHP questionnaires.

- (4) Compare the relative importance of each criterion and apply the comparison against the criteria.
- (5) Determine the priority of each criterion.
- (6) Ensure that the consistency index (C.I.) is less than or equal to 1 in order, which indicates that errors are within an acceptable range, and ensure that the consistency ratio (C.R.) is less than or equal to 0.1, which indicates that the questionnaire survey data are valid.
- (7) Determine the relative WV of each criterion and Construct the AHP assessment model.
- (8) Assess individual solutions, rank multiple solutions, or select the optimal solution.

Figure 3 illustrates the criteria and AHP hierarchical framework established through the literature review and the mutual agreement by the experts in the Delphi process. Of the factors affecting interdisciplinary curricula and design practices, the main criterion for evaluating interdisciplinary technological product design is the consideration of both aesthetic perceptions and product functions. The subcriteria influencing aesthetic perception are freehand sketching, sketching in 3D, and designing color schemes, whereas those influencing product function are human factor engineering, universal design, as well as science and technology. After each criterion was determined, the AHP hierarchical framework was established (Fig. 3).

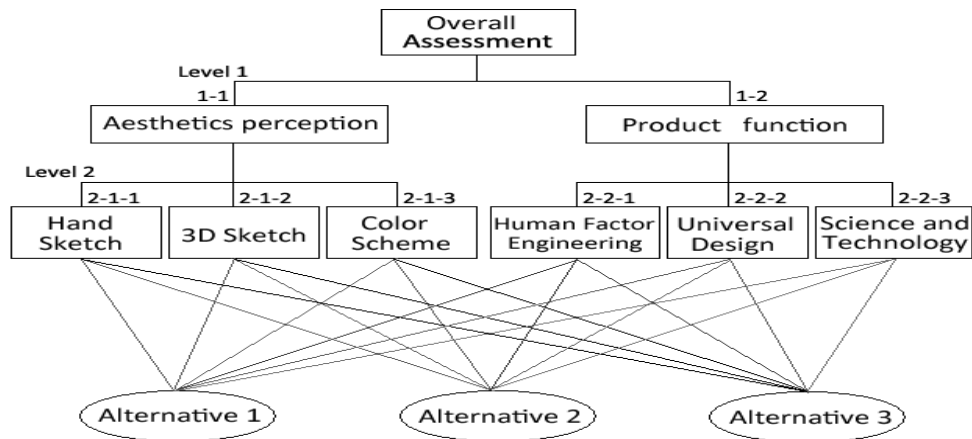


Figure 3. The AHP hierarchical framework.

Implementing the AHP

The AHP was implemented by first determining the criteria of the assessment system and then compiling, distributing, and collecting the AHP questionnaires. Subsequently, the internal consistency of the constructs was examined. The AHP questionnaires were distributed to 50 designers, industrial design engineers, product production managers, and CEOs of enterprises, and 70 were distributed to professors and students at departments of fashion design, industrial design, visual design, and marketing management. After invalid questionnaires and valid questionnaires with large variances were removed, 82 responses were considered valid. The average values of the 82 valid questionnaire items were calculated. Table 1 shows the comparison against criteria results for the overall assessment.

Research results

The AHP multiattribute decision-making model revealed that among the interdisciplinary courses, aesthetic perception and product function were equally crucial ($WV = 0.5$ for both courses). Additionally, the WVs for the main subcriteria

were in the order of science and technology (0.195), sketching in 3D (0.185), universal design (0.175), and designing a color scheme (0.170). The effectiveness of completing the aforementioned courses significantly influenced interdisciplinary product design. Sethi et al. mentioned the growing prevalence of cross-functional teams in new product development projects (Sethi et al., 2011). In addition to assisting students in enhancing their creativity and developing multifunctional products, completing interdisciplinary courses can reduce the likelihood of conflicts of opinion arising between team members with expert knowledge in different domains. Codesigning has been regarded as a critical factor in the success of many service design projects, and various benefits have been attributed to adopting the codesign approach (Steen et al., 2011).

Interdisciplinary courses can assist students in developing technological products that have a short lifecycle. The AHP multiattribute decision-making model established in this study may serve as a reference for assessing student learning effectiveness in design courses. Because the proposed model is highly adaptive, it is easy to modify and maintain in the future, and can be applied in areas unrelated to industrial cooperation and industry-based courses.

Table 1. Relative WV* for each criteria obtained by AHP process

Overall Assessment (WV = 1)				
Level	Criterion	Comparison against	WV	Overall WV
1-1	Aesthetic perception	1	0.5	
1-2	Product function	1	0.5	
Aesthetic perception (WV = 0.5)				
2-1-1	Freehand sketching	1	0.29	0.145
2-1-2	Sketching in 3D	1.33	0.37	0.185
2-1-3	Designing a color scheme	1.11	0.34	0.170
Product function (WV = 0.5)				
2-2-1	Human factor engineering	1	0.26	0.130
2-2-2	Universal design	1.25	0.35	0.175
2-2-3	Science and technology	1.66	0.39	0.195
Remark	Level 2-1, CR = 0.00139 (< 0.1); Level 2-2, CR = 0.00793 (< 0.1); thus, internal consistency was achieved.			

* WV = Weighting value.

CASE STUDY

The purpose of course design is to provide theoretical knowledge and practical training for students and to assist them in reducing the gap between their learning and industrial practices. Meanwhile, the learning process in authentic practices gives rise to the development of students' technological design and scientific skills (Logman et al., 2015). In this study, the process of designing a multifunctional scale ruler was investigated as a case study to demonstrate the application of the decision-making model through determining which criteria significantly influenced the multifunctional design of the ruler. The research results may serve as a reference for designing interdisciplinary courses.

Application of a multifunctional scale ruler

A scale ruler is an auxiliary design tool typically used by architects and interior designers. Other objects that are often used by architects and interior designers are pens, cameras, video recorders, lighting devices, universal serial bus (USB) memory devices, pointers, and radiation detector (Figure 4). Because of advancements in technology, electronic devices have been miniaturized and are generally light in weight. The design concept of the multifunctional scale ruler is the integration of multiple devices that architects and interior designers use often in their work.

Design of the multifunctional scale ruler

The multifunctional scale ruler (Figure 5) functions as (a) light device, (b) video recorder, (c) pen, (d) camera, (e) scale ruler, (f) radiation detector device, (g) USB device and SD memory card and (h) laser pointer pen. The purpose of a multifunctional scale ruler is to realize a creative concept as a multifunctional product that is easy to use, portable, and enhances work performance.

The laser pointer pen can present three colors (red, green, and blue) and eight statuses. In addition to functioning as a typical pointing device, the pointer can also facilitate communication through transmitting and exchanging message over long distances. This additional function, which was not uncovered during the initial design stage, adds practical value to the original design.

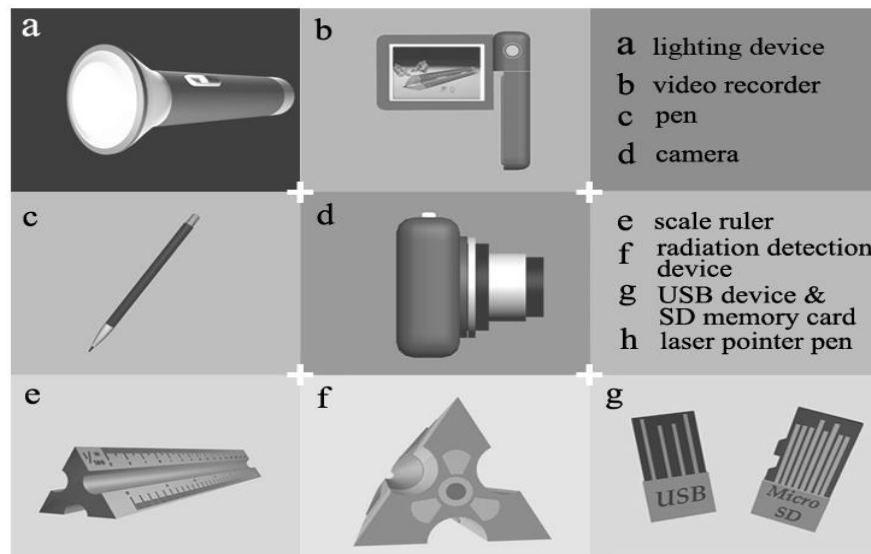


Figure 4. Devices used by architects and interior designers.

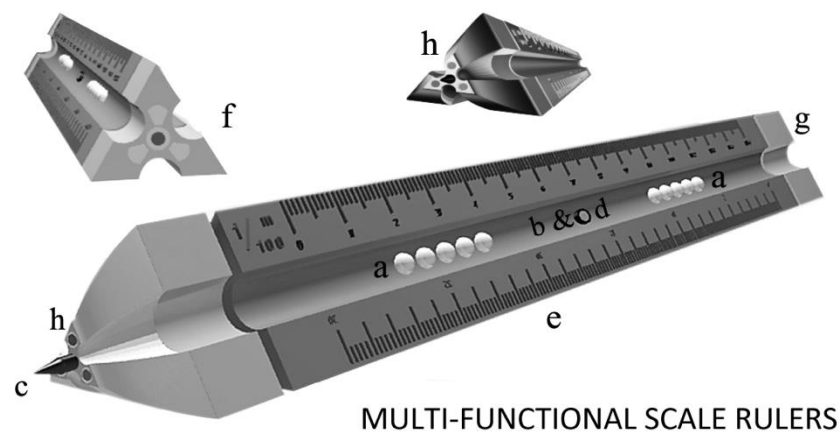


Figure 5. Multifunctional scaleruler.

Case assessment

This study investigated the effectiveness of applying the AHP multiattribute

decision-making model to evaluate the criteria for designing interdisciplinary courses. The alternative functions identified through assessing the multifunctional design of the ruler were camera, video recorder, and flashlight; radiation detector, pen, and pointer; and physical products.

In this study, 80 questionnaires were distributed to product designers, industrial design engineers, production managers, CEOs, as well as professors and students from fashion design, industrial design, visual design, and marketing management departments. Overall, 56 valid questionnaires were returned. Table 2 shows relative WVs from the case study. Regarding physical products, apart from the low WV for science and technology (Level: 2-2-3), the criteria achieved relatively high WVs, indicating that the camera, video recorder, flashlight, radiation detector, pen, and pointer influenced the design of the multifunctional scale ruler. Litzinger et al. mentioned that integrating creative processes from various engineering curricula can enhance design outcomes (Litzinger et al., 2015). In other words, commercializing multifunctional products requires a comprehensive understanding of how the functions of technological products can be integrated to design products that can be commercialized and exceed the utilitarian needs of customers and enhance customer satisfaction (Chitturi et al., 2008).

Table 2. Calculating each criterion's relative WVs* for the case in this study

Criterion and Level	Aesthetic perception (0.5)			Product function (0.5)			Overall WV	
	2-1-1 (0.29)	2-1-2 (0.37)	2-1-3 (0.34)	2-2-1 (0.26)	2-2-2 (0.35)	2-2-3 (0.39)		
I	WV	0.58	0.11	0.15	0.13	0.12	0.54	0.273
	Overall	0.084	0.020	0.026	0.017	0.021	0.015	
II	WV	0.22	0.34	0.35	0.42	0.48	0.38	0.368
	Overall	0.032	0.063	0.060	0.055	0.084	0.074	
III	WV	0.20	0.55	0.5	0.45	0.40	0.08	0.361
	Overall	0.029	0.102	0.085	0.059	0.070	0.016	
Overall WV				1.002				

* WV = Weighting value.

SUGGESTIONS AND CONCLUSION

Suggestions

1. A scale ruler is a common engineering tool. The multifunctional scale ruler indicated in the aforementioned cases is an innovative industrial tool with practical application value. The assessment results of the AHP model indicated that interdisciplinary knowledge is a critical factor for designing functional products. Interdisciplinary knowledge can be obtained through interdisciplinary curriculum and off-campus internships. These means are all effective for assisting students in acquiring interdisciplinary knowledge.
2. Moreover, Kurilovas, & Zilinskiene recommended using the AHP for expert evaluations of learning quality (Kurilovas, & Zilinskiene, 2012). Therefore, the AHP multiattribute decision-making model can be adopted as an auxiliary tool

for exploring student learning outcomes.

3. The interdisciplinary curriculum planning model based on the combination with industrial practice proposed in this study could be the reference for new courses.

CONCLUSION

Currently, interdisciplinary courses and academia–industry collaboration are being actively promoted in Taiwanese education to cultivate students' individual core abilities in diverse learning and employability. Because sketching, hand drafting, 3D illustration, color planning, and aesthetics are required architectural and interior design courses, applying courses for designing architectural and interior design equipment enables students to easily synthesize the material from these courses. Promoting interdisciplinary courses facilitates improving the ability of architecture and interior design students to create environmental designs and sustainable construction materials. In addition to displaying ideal functionality, commercial products must satisfy customer and market demands. According to this study, although engineering students' current professional education is beneficial, interdisciplinary product design courses must still equally emphasize aesthetic perceptions and product functionality design. This paper provides a quantitative evaluation model to improve the educational effectiveness of new interdisciplinary courses.

The DAHP decision-making model proposed in this study may serve as a reference for designing interdisciplinary courses. The case analysis facilitated understanding the significant influence of the interdisciplinary courses, enabling adjustment of the course WVs. In addition, the DAHP multiattribute decision-making model is highly adaptive, easy to use, and simple to maintain in the future.

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3. The multifunctional scale ruler designed in this study received the Bronze Award at the 26th International Invention and Innovation Exhibition in Malaysia in 2015.

REFERENCES

- Al-Marzouqi, M. &El-Naas, M.H. (2012).The Role of Environmental Design Competitions in Engineering Education, *Int. J. Eng. Educ.*, 28(4), 959-965.
- Blijlevens, J. Gemser, G. &Mugge, R. (2012). The importance of being 'well-placed': the influence of context on perceived typicality and esthetic appraisal of product appearance. *Acta Psychol.*, 139, 178–186.
- Carbon, C.C. (2011). Cognitive mechanisms for explaining dynamics of aesthetic appreciation, *i-Perception*, 2, 708–719.
- Cardenas, C. (2011).A multidisciplinary approach to teach the design of socially relevant computing systems for social change, *Int. J. Eng. Educ.*,27(1), 2011, pp. 3–13.

- Chitturi, R., Raghunathan, R. & Mahajan, V. (2008). Delight by design: the role of hedonic versus utilitarian benefits, *J. Marketing*, 72(3), 48–63.
- Crilly, N., Moultrie, J., & Clarkson, P.J. (2009). Shaping things: intended consumer response and the other determinants of product form, *Des. Stud.*, 30, 224–254.
- Dagman, J., Karlsson, M.A. & Wikström, L. (2010). Investigating the haptic aspects of verbalised product experiences, *Int. J. Design*, 4(3), 15–27.
- Daniels, M., Cajander, A. Clear, T. & McDermott, R. (2015). Collaborative technologies in global engineering: new competencies and challenges, *Int. J. Eng. Educ.*, 31(1B), 267–281.
- Friedman, K. (2003). Theory construction in design research: criteria: approaches, and methods, *Des. Stud.*, 24, 507–522.
- Gnaur, D., Svidt, K. & Thygesen, M.K. (2015). Developing students' collaborative skills in interdisciplinary learning environments, *Int. J. Eng. Educ.*, 31(1B), 257–266.
- Hafeez, K., Zhang, Y. & Malak, N. (2002). Determining key capabilities of a firm using analytical hierarchy process, *Int. J. Prod. Econ.*, 76 (1), 39–51.
- Hassenzahl, M. (2004). The interplay of beauty, goodness, and usability in interactive products, *Hum-Comput. Interact.*, 19(4), 319–349.
- Hassenzahl, M. & Monk, A. (2010). The inference of perceived usability from beauty, *Hum-Comput. Interact.*, 25(3), 235–260.
- Heilman, R.M., Crisan, L.G., Houser, D., Miclea, M., & Miu, A.C. (2010). Emotion regulation and decision making under risk and uncertainty, *Emotion*, 10, 257–265.
- Hsueh, S.L., Lee, J.R. & Chen, Y.L. (2013). DFAHP multicriteria risk assessment model for redeveloping derelict public buildings, *Int. J. Strateg. Prop. Manag.*, 17(4), 333–346.
- Kurilovas, E. & Zilinskiene, I. (2012). Evaluation of quality of personalised learning scenarios: an improved MCEQLS AHP method, *Int. J. Eng. Educ.*, 28(6), 1309–1315.
- Leder, H., Belke, B., Oeberst, A., & Augustin, M.D. (2004). A model of aesthetic appreciation and aesthetic judgments, *Br. J. Psychol.*, 95, 489–508.
- Li J.Y. & Shieh, C.J. (2016). A Study on the Effects of Multiple Goal Orientation on Learning Motivation and Learning Behaviors, *Eurasia Journal of Mathematics, Science & Technology Education*, 12(1), 161-172.
- Litzinger, T., Zappe, S., Hunter, S. & Mena, I. (2015). Increasing integration of the creative process across engineering curricula, *Int. J. Eng. Educ.*, 31(1B), 335–342.
- Maffei, A., Akillioglu, H. & Lohse, N. (2014). Analysis of the student perception of the link between product and production system: towards effective strategies to teach the holistic nature of product design, *Int. J. Eng. Educ.*, 30(6A), 1357–1366.
- Maier, J.R.A. & Fadel, G.M. (2009). Affordance-based design methods for innovative design, redesign and reverse engineering, *Res. Eng. Des.*, 20(4), 225–239.
- Masry M., Kang, D.J. & Lipson, H. (2005). A freehand sketching interface for progressive construction of 3D objects, *Comput. Graphics*, 29(4), 563–575.
- Mccrae, J. & Singh, K. (2009). Sketch-based path design, *GI 09 Proceedings of Graphics Interface*, 2009, 95–102.
- McLaughlan, R.G. (2007). Instructional strategies to educate for sustainability in technology assessment, *Int. J. Eng. Educ.*, 23(2), 201–208.
- Mihelcic, J.R., Eatmon, T.D., Harris, R.A. & Muga, H.E. (2007). Engineering Sustainable Construction Materials for the Developing World: a Meta-discipline Approach to Engineering Education, *Int. J. Eng. Educ.*, 23(6), 1116–1125.
- Noble, C.H. & Kumar, M. (2012). Exploring the appeal of product design: a grounded, value-based model of key design elements and relationships, *J. Prod. Innovat. Manag.*, 27, 640–657.
- Park, S., Choi, D. & Kim, J. (2004). Critical factors for the aesthetic fidelity of web pages: empirical studies with professional web designers and users, *Interact. Comput.*, 16(2), 351–376.
- Ryu S. & Sandoval, W.A. (2015). The Influence of Group Dynamics on Collaborative Scientific Argumentation, *Eurasia Journal of Mathematics, Science & Technology Education*, 11(2), 335-351.
- Sethi, R., Smith, D.C. & Park, C.W. (2011). Cross functional product development teams, creativity and the innovativeness of new consumer products, *J. Marketing Res.*, 38(1), 2001, pp. 73–85.
- Shieh, C.J., Zhifang, S. & Yeh, S.P. (2014). Key success factors in cultivating students' learning motivation, *Int. J. Eng. Educ.*, 30(2), 326–332.

- Shyr, W.J. & Lo, T.C. (2012). The Working Competency Items for Energy Technology: A Three-Stage Empirical Method, *International Journal of Engineering Education*, 28(3), 599–605.
- Steen, M., Manschot, M. & De Koning, N. (2011). Benefits of co-design in service design projects, *Int. J. Design*, 5(2), 2011, pp. 53–60.
- Xenakisa, I. & Arnellosb, A. (2013). The relation between interaction aesthetics and affordances, *Des. Stud.*, 34(1), 57–73.

