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Article

Study of Relationship between Curriculum Components and Learning Achievements

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Abstract: The importance of core courses in professional programs at universities and their impact on the final graduation projects was investigated in the field of industrial design, focusing on Model Making, Rendering Techniques, and Design Aesthetics. The courses exhibiting the strongest correlation with the graduation project's grades were determined. Through an analysis of secondary data from these courses and graduation projects, the subject most relevant to the presentation of the final learning outcomes was identified. The research findings provide a foundation for strengthening the curriculum, adjusting course planning, and enhancing students' professional development. The study results offer valuable insights into the effectiveness of core courses in shaping the final learning outcomes and can guide universities in developing improved curricula to enhance students' professional growth.

Keywords: Curriculum items, Learning outcomes, Curriculum enhancement

1. Introduction

In recent years, the 'capstone course' has been regarded as the quintessential examination course for assessing learning outcomes (Hauhart & Grahe, 2015). By implementing summative courses, the final learning results of students effectively demonstrate the teaching effectiveness of the department, and the extent to which the department's core competencies have been achieved is evaluated (Gardner & Van der Veer, 1998). Therefore, the capstone course is widely used to enhance the learning experience in the senior year (Fwu, 2017). Consequently, an increasing number of universities are promoting the capstone course and making it a mandatory component to assess students' four-year learning outcomes (Gardner & Van der Veer, 1998). In Industrial Design, the capstone course presentation encompasses graphic design skills, model-making techniques, aesthetic sensibilities, and other relevant aspects. Therefore, the subjects covered in the preceding academic years have varying degrees of influence on the outcome. Hence, it is essential to analyze the relationship between the regular courses and the capstone course to strengthen the curriculum.

2. Literature Review

In recent years, the 'capstone course' has been regarded as the typical examination course for assessing learning outcomes (Hauhart & Grahe, 2015). Through the implementation of summative courses, the final learning results of students effectively demonstrate the teaching effectiveness of the department, evaluating the extent to which the department's core competencies have been achieved (Gardner & Van der Veer, 1998). Therefore, the capstone course is widely utilized to enhance the learning experience in the senior year (Fwu, 2017). Consequently, an increasing number of universities are promoting the capstone course and making it a mandatory component to assess students' four-year learning outcomes (Gardner & Van der Veer, 1998). In Industrial Design, the presentation of the capstone course encompasses graphic design skills, model-making techniques, aesthetic sensibilities, among others. Thus, the subjects studied during the academic years have varying degrees of influence on the outcome. Therefore, it is essential to analyze the relationship between the regular courses and the capstone course to strengthen the curriculum.

Successful capstone design courses often incorporate interdisciplinary teams, real-world projects, and industry partnerships (Brown & Adams, 2016), demonstrating the effectiveness of such courses in promoting learning outcomes and student engagement. In a survey conducted by Kim (2018) involving 291 undergraduate students who completed capstone courses, it was found that these courses significantly enhanced problem-solving skills, critical thinking, and team collaboration (Kim, 2018). Moreover, Wang (2021) compared three different types of capstone courses—thesis-based, project-based, and seminar-based—and suggested that project-based capstone courses were the most effective in promoting learning outcomes and preparing students for real-world

challenges (Wang, 2021)

However, challenges persist in the design and implementation of capstone courses, including issues related to teaching resources and evaluation, as well as the perceptions and engagement of both students and teachers (Mueller & Schramm, 2019). Ashraf and Mahmood (2018) conducted a review focusing on the effectiveness of project-based capstone courses in engineering education. Their study, which encompassed an analysis of 23 relevant studies from international academic journals and conference proceedings, highlighted the positive impact of project-based capstone courses on students' academic achievements, professional skills, and career development. Furthermore, these courses were noted to enhance students' innovation and teamwork abilities. However, certain limitations were identified, such as the requirement for high-quality project design and implementation (Ashraf & Mahmood, 2018).

The analytical application of secondary data is a common research method. The literature review result showed that secondary data analysis is a valuable and underutilized research method to provide valuable insights and contribute to knowledge production in a variety of fields (Johnston, 2014). It is most often used in the medical field, such as to understand the latest changes in the global and Chinese cancer burden and to compare cancer data in China with other regions to adjust medical policies (Chen et al., 2021). For the COVID-19 epidemic, the analysis of secondary data has become an important research tool, including the understanding of nosocomial infection of patients and the response to decision-making (Hughes et al., 2020). The correlation between the virus and the environment was also explored (Tosepu et al., 2020) along with the impact of the epidemic on the regional economy (Susilawati et al., 2020). Secondary data analysis is widely used in education, too. The advantages and disadvantages of conducting educational research through the use of secondary data were explored, and directions for future research were proposed (Lee & Park, 2018; Yang & Huang, 2019; Koon, & Ho, 2021; Neumann, & Ziegler, 2019; Kilinc, & Ertekin, 2020). Secondary data analysis is also applied to industrial design. Secondary data analysis helped designers better understand market trends, consumer preferences, and product performance, leading to more successful design outcomes (Liu & Guo, 2020). Based on the literature review, it was found that capstone courses have been widely used by universities to evaluate students' learning outcomes and teaching effectiveness. Capstone courses enhanced students' professional skills and problem-solving abilities and promoted academic and professional development through six types of capstone courses: comprehensive examination, thesis-based, project-based, clinic- and internship-based, seminar-based, and portfolio-based courses (Henscheid,2000). Successful capstone design courses often involve interdisciplinary teams, real-world projects, and industry partnerships but still have limitations.

Industrial design integrates aesthetics and engineering as an applied subject. In the fourth year of university, students take the graduation project as a capstone course in which they analyze and summarize problems to form design specifications, develop ideas, and present them through various techniques such as painting and model-making. To implement and realize ideas, various factors must be considered, including the market, manufacturing, and material application. The final result needs to conform to the aesthetic concept, and thus the students' ideas must integrate aesthetics (software) and engineering (hardware). The skills of concept expression, including drawing and model-making, are important basic skills, and the expression skills are the foundation of aesthetics. These three subjects are important in the industrial design curriculum, and it is important to determine which subject has the highest correlation with learning outcomes and graduation projects. This information can be used as a basis for curriculum strengthening and the identification of the relationship between these subjects and the achievement of learning outcomes. Thus, this study was conducted using the grades of the three subjects and the corresponding graduation project grades to research and understand the correlation between them. The results of this study provide a reference for course planning.

3. Course Description

Model making, rendering technology, and design aesthetics stand as pivotal disciplines within industrial design. Below are the outlined course objectives and content for each.

3.1. Model Making

The model-making course is designed to introduce concepts and foster students' proficiency in working with three-dimensional shapes. Through practical, hands-on exercises, students refine their abilities in shaping and detailing. The model-making course is positioned as one of the fundamental practical courses within the design department. Its primary goal is to equip students with the skills necessary to transform abstract ideas into tangible three-dimensional designs. The essence of model-making lies in validating ideas by creating sketch models during the design process, showcasing the resultant design, and effectively communicating design intentions to third parties. The curriculum introduces the manufacturing process and explores various related material properties. Further details regarding class structure and assignments can be found in Figs. 1 and 2.

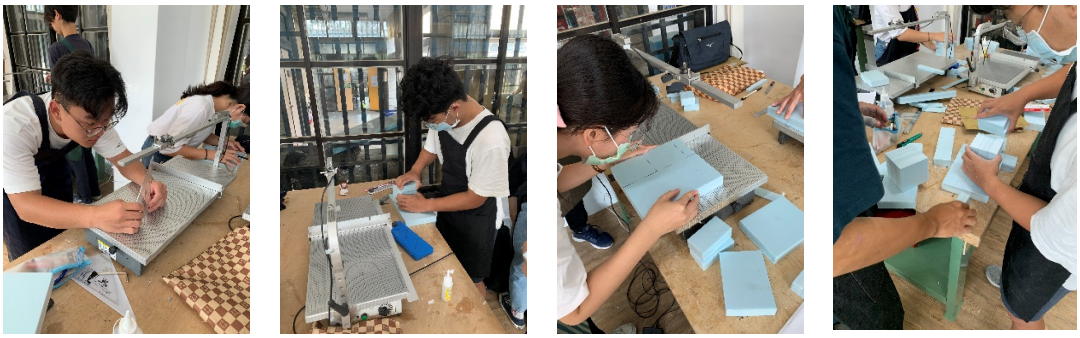

Fig. 1. The class structure of the model-making course.

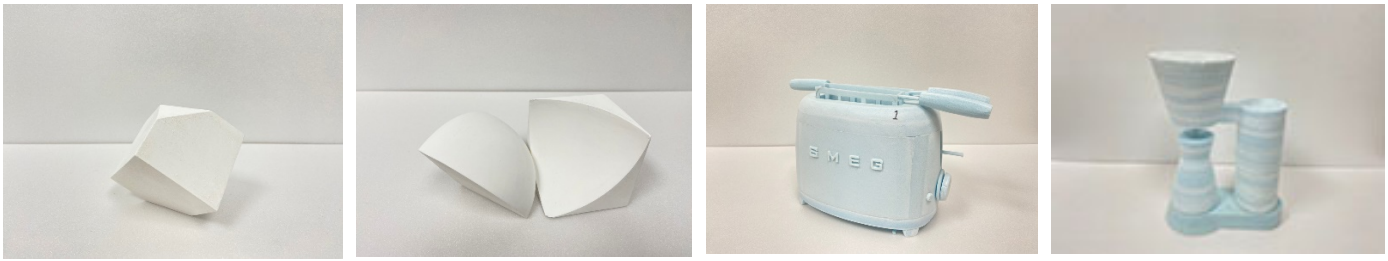

Fig. 2. Presentation of the Model-making Coursework.

3.2. Rendering Techniques

The Rendering Techniques course aims to teach sketching, drawing, and hand-painted techniques to visually present ideas. This course enables students to develop a three-dimensional concept of the product and modify designs during the process. Emphasizing the mastery of quick product description and the ability to fully express the texture and detailed features of the product through fine drawing, the course focuses on enhancing these skills. These expression techniques offer advantages such as speed, conciseness, and convenience, enabling designers to record and express their inspiration at any moment. The course requires extensive practice of various forms of hand-painting skills, with homework assignments focused on skill performance detailed in Fig. 3. Both the Rendering Techniques course and the model-making course entail numerous hands-on assignments, rendering them relatively challenging for students.

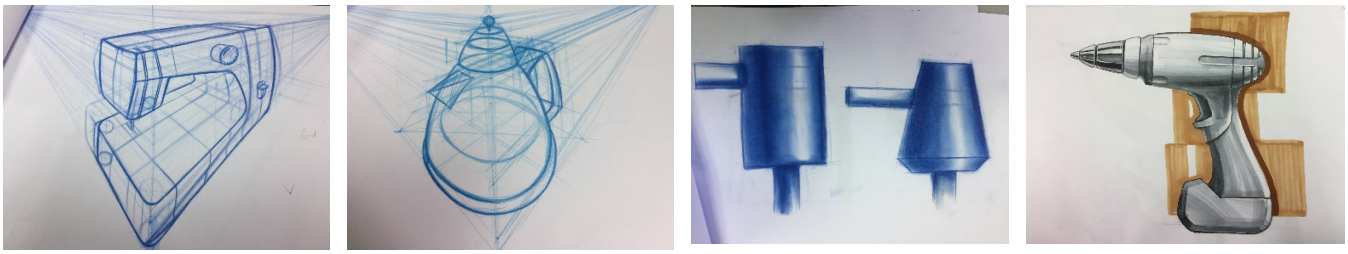

Fig. 3. Presentation of Rendering Techniques assignments.

3.3. Design Aesthetics

The Design Aesthetics course belongs to the field of applied aesthetics in design. This course is offered to enhance students' ability to appreciate and achieve aesthetics. The course content is divided into two parts: "theory" and "practice". The teaching approach is based first on appreciation, followed by analysis and discussion to elucidate the relationship between design, aesthetics, and life. Through this course, students gain a deeper understanding of the application of aesthetics in design. In the classroom, students exchange and discuss ideas on various themes, gradually establishing a foundation in aesthetic concepts. The curriculum covers design history, design introduction, style analysis, themed discussions, design appreciation and evaluation, among others. The course integrates appreciation analysis, theoretical explanation, group discussion, and communication. Design Aesthetics is an interactive discussion-based course.

3.4. Graduation Project

The Graduation Project is a capstone course in the design department. It serves as a comprehensive assessment of students' four-year undergraduate education. Guided by a specific topic, students identify and summarize problems, formulate design specifications, and execute concept development, evaluation, refinement, 3D modeling, and presentation following established guidelines. They leverage the knowledge and skills acquired throughout their university studies to complete the undertaking. Through staged deliverables, oral reports, exhibition planning, and other activities, students learn to independently synthesize and apply their accumulated knowledge in practice. The aim is to cultivate students' design sensibility for solving problems. The presentation and evaluation of graduation project outcomes are depicted in Figs. 4 and 5.

Fig. 4. Presentation of the Graduation Project results.

Fig. 5. The Graduation Project Evaluation Activity.

4. Results and Discussion

Using the secondary data analysis method, accumulated data for Model-making, Rendering Techniques, Design Aesthetics, and Graduation Projects from 2019 to 2021 were collected. After removing incomplete data, 71 data points were used for statistical analysis. Correlation analysis was carried out using SPSS, and the results are shown in Tables 1–3.

4.1. Descriptive Statistics

71 sets of data were compiled over three consecutive years. The average grade for the graduation project was 80.17, with a standard deviation (SD) of 6.941. The average grade for the Model Making course was 78.06, with an SD of 7.109. Similarly, the average grade for the Rendering Techniques course was 77.54, with an SD of 8.791. Moreover, the average grade for the Design Aesthetics course was 81.93, exhibiting an SD of 3.611. The standard deviations of the course grades indicated that the grade distribution in the Design Aesthetics course was relatively concentrated, while that of the performance-skill course was relatively scattered (see Table 1).

Table 1. Descriptive Statistics of Four Subjects.

Course	N	Min	Max	Mean	Std. Deviation
Graduation Project	71	60	94	80.17	6.941
Model- making	71	59	94	78.06	7.109
Rendering Techniques	71	59	95	77.54	8.791
Design Aesthetics	71	70	91	81.93	3.611

4.2. Correlation Analysis

Table 2 presents the results of the correlation analysis. A significant correlation was observed between the grades of the Model Making, Rendering Techniques, and Design Aesthetics courses and the Graduation Project, aligning with the research hypothesis. The Pearson correlation coefficient indicated a moderate correlation (0.439) between Model Making and the Graduation Project,

while Rendering Techniques (0.264) and Design Aesthetics (0.337) displayed relatively less significant correlations with the Graduation Project. These findings indicate that Model Making, Rendering Techniques, and Design Aesthetics are significantly associated with the Graduation Project.

Table 2. Result of correlation analysis of grades of each subject and grade of graduation projects.

		Model-making	Rendering Techniques	Design Aesthetics
Graduation Project	Pearson Correlation	0.439 **	0.264 *	0.337 **
	Significance (2-tailed)	0.000	0.026	0.004
	N	71	71	71

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

In the Model-making course, the course planning emphasized basic knowledge and manual skills in the first half of the semester. This content covered factory safety regulations, an introduction to various machines and tools, material properties, manufacturing procedures, and basic manual skill exercises. During the latter part of the course, the focus shifted to advanced manual skill exercises and comprehensive application scenarios. We conducted an analysis of the midterm and final grades from the 71 Model-making courses, and the results are presented in Table 3. The findings revealed a significant correlation between the midterm and final grades, suggesting that the continuity of learning content in the Model-making course was crucial, and the earlier stage learning laid the foundation for the later stage.

Table 3. Correlation Analysis Results of the Model-Making Course Grades.

		Final Grades
Midterm Grades	Pearson correlation	0.667 **
	Significance (2-tailed)	0.000
	N	71

** Correlation is significant at the 0.01 level (2-tailed).

4.3. Strategy for Course Enhancement

According to the research findings, it was evident that the model-making course had a significant impact on the overall development of design expertise. Therefore, it became crucial to consider methods to further enhance the course for improving student learning outcomes. Consequently, a SWOT analysis was conducted to evaluate the content and characteristics of the course, aiming to gain a clearer understanding of its strengths and weaknesses. The results of the SWOT analysis for the model-making course are presented in Table 4.

Table 4. SWOT Analysis Results for the Model-Making Course.

Strength	Weakness
-Equip students with practical skills -Foster students' proficiency in Model-making -Acquire knowledge in generating production-related information -Develop expertise in presenting models effectively	The arduous and demanding nature of the learning process can result in a decrease in students' motivation to learn, and individuals who lack patience may prematurely discontinue their studies, thereby impeding the development of their fundamental design skills.
Opportunity	**Threat**
-By making appropriate adjustments to the curriculum, we can enhance learning effectiveness by improving students' motivation to learn. -Integrating the topic of completion with other course content can help strengthen students' motivation to learn.	-The exorbitant expense associated with course materials frequently discourages students from acquiring supplementary practice resources, thus hindering their capacity to attain a comprehensive grasp of the subject matter. -The introductory model-making course is constrained to a solitary semester, posing challenges for students in achieving a comprehensive comprehension of the subject matter. Moreover, the absence of continuity in the curriculum further impedes the depth of their learning experience. -The widespread adoption of 3D printing technology among students has led to a displacement effect on traditional model-making courses.

The SWOT analysis resulted in the following findings. The model-making course provided students with practical skills and the ability to create production-related information while mastering overall modeling presentation skills. However, the tedious and challenging nature of the learning process demotivated students and affected their foundational design skills negatively. To address this weakness, curriculum adjustments are necessary to enhance learning effectiveness and improve students' motivation. Integrating model-making with other course content has the potential to motivate students. Despite these opportunities, there were threats to the course, such as the high cost of materials, the limited duration of the course, and the disruptive effect of 3D printing technology on traditional model-making methods. These threats can be mitigated through creative solutions, ensuring that the model-making course remains relevant and effective for students.

The strategies for strengthening the curriculum are proposed as follows:

(1) Engaging and interesting learning process
- Interactive activities: Activities such as quizzes, games, and interactive exercises can make the learning process engaging and less monotonous for students.
- Group projects: Collaborative projects encourage creativity and teamwork, empowering students to take ownership of their work.
- Real-life examples: Practical examples from everyday items like toasters, printers, and coffee machines can help students apply their skills, making the learning process more relevant and interesting.

(2) Incentives or rewards for successful completion
- Recognition for course completion: Providing awards or special acknowledgment can incentivize students to successfully finish the course.
- Milestone rewards: Recognizing specific achievements, such as completing challenging projects or mastering particular skills, can sustain students' motivation and involvement.

(3) Supportive learning environment
- Encouraging questions and seeking help: Creating an open and supportive atmosphere encourages students to seek assistance when needed, preventing frustration during the learning process.
- Additional support resources: Offering resources like online tutorials or peer mentoring programs can provide extra guidance and support.

(4) Affordable or free course materials
- Providing necessary materials: The course should supply essential production materials, potentially charging a fee based on a structured plan. To minimize waste, teaching assistants should oversee material distribution and implement a system for reusing resources, teaching students resourcefulness.
- Encouraging material sharing: Promoting material sharing among classmates can help reduce the overall cost burden.

(5) Planning and offering advanced/specialized model-making courses
- Providing advanced or specialized courses allows students to further develop their skills and explore specific interests.

(6) Collaboration across disciplines
- Integrating model-making and 3D printing into broader topics: Collaborating with other departments allows for the creation of more relevant and appealing courses that align with industry trends. Incorporating 3D printing technology can offer novel learning experiences and foster cross-disciplinary cooperation.

5. Conclusion

To investigate the relationship between curriculum components and students' learning outcomes, secondary data analysis was conducted on the Model-making, Rendering Technology, Graduation Project, and Design Aesthetics courses along with students' grades in industrial design. The analysis yielded the following conclusions.

There existed a significant relationship among the Model-making, Rendering Techniques, Design Aesthetics, and the Graduation Project. Specifically, the model-making course exhibited a moderate correlation, while the Rendering Techniques and Design Aesthetics courses demonstrated less significant correlations with the Graduation Project. The correlation analysis indicated a moderate relationship between the Model-making course and the Graduation Project, emphasizing the need to enhance students' model-making abilities in future courses.

Presently, limitations in equipment and resources result in unequal learning opportunities within the class, necessitating appropriate strategies in future curriculum planning. Notably, the Model-making course displayed high correlations with other courses. In the context of the Graduation Project, the quality and detail of models significantly influenced the final design concept and subsequent grade. Consequently, improved learning outcomes in the Model-making course directly impacted the quality of the

final Graduation Project model.

Conversely, a less significant correlation was observed between the rendering technique course and the Graduation Project. One potential reason for this disparity was that the project demanded computer-based drawings for presentation, whereas the rendering technique course focused on hand-drawn sketches, leading to a skills mismatch. Further investigation is needed to compare the correlation between the computer graphics course and the Graduation Project.

Similarly, the correlation analysis highlighted a less significant relationship between Design Aesthetics and the Graduation Project, attributed to the diverse topics within the project and their varying emphases. For instance, while daily necessities prioritize aesthetic standards, tool products emphasize practicality, influencing the correlation between Design Aesthetics and the Graduation Project courses.

In summary, the Model-making, Rendering Techniques, and Design Aesthetics courses exhibited a significant influence on the Graduation Project. While the Model-making course demonstrated a moderate correlation with the Graduation Project, the Rendering Techniques and Design Aesthetics courses exhibited less significant correlations. Enhancing the Model-making course is crucial for improving learning outcomes, given its significant impact on the final design concept and evaluation. The less significant correlations observed in the rendering technique and Design Aesthetics courses can be attributed to the prevalence of computer-based drawings and the diverse emphases within various project themes, respectively.

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Conflicts of Interest: The author declares no conflict of interest.

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