Discussion about the Course Optimization and Innovation Relating to Industrial Design Engineering in Contemporary Colleges and Universities

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Abstract. Contemporarily, for better adapting to the new changes caused by the educational reform in colleges and universities and domestic industrial upgrading, this paper focuses on discussing a specific course reform relating to "Industrial Design Engineering" which is the core course of industrial design specialty. Firstly. comprehensive reviews of both theoretical teaching and practical training methodology in different domestic colleges and universities are provided. A detailed reform case (includes the optimization of theoretical teaching and the characteristic innovation of practical training) schemed by Fuzhou University is further demonstrated and analyzed. It hopes that the experience sharing can contribute to domestic higher education co-construction, and will be benefit to future educational improvement of industrial design and emerging engineering personnel training program.

Keywords: Industrial design engineering, course reform, university-enterprise cooperation, design and commercialization.

1 Introduction

In the 1980s, International Council of Societies of the Industrial Design (ICSID) ever defined industrial design as: "the mass production of industrial products, by virtue of training, technical know-how, experience and feelings and give visual materials, structure, shape, color, surface processing and decoration to a new quality and qualifications" [1]. In this traditional context, "Industrial Design Engineering" as the core course of industrial design education in Chinese colleges and universities, its theoretical teaching purpose was: " enabling students to understand the basic compositions & principles of both mechanisms and structures commonly used in various products, and further to be familiar with relevant processing and technical requirements"; while the practical training purpose was: " enriching students' engineering knowledge and promoting the transformation from the design ideas to engineering practice".

However, in the past decade, there was a new round of technological revolution and industrial transformation happened in China, meanwhile domestic higher education started emphasizing on the independent innovation and development. In such new context, on the one hand, social employers set higher requirements to industrial designers in terms of enhancing the thinking

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innovation, technology application, comprehensive development, and other skills [2]; On the other hand, due to the constantly increasing number of undergraduates caused by the enrollment expansion in domestic colleges and universities, the quality evaluations of both higher education and social employment had to face unprecedented pressures, which finally produced a new challenge to the traditional teaching methods and content of industrial design specialty [3-4].

For better adapting to above changing trends, this study firstly reviews and summarizes the teaching and practical characteristics relating to the "Industrial Design Engineering" course in multiple domestic colleges and universities. While learning those diverse experiences, it recommends that other colleges and universities should also be aware of the importance of optimizing and reforming similar courses rely on their actual conditions. Then a case study about the "Industrial Design Engineering" course optimization and innovation schemed by Fuzhou University will be discussed in detail. It hopes to be able to provide some inspirations for supporting contemporary teaching reform, and to promote educational development in terms of domestic industrial design to match with international first-class level.

2 Review of the teaching and practical characteristics in multiple domestic colleges and universities

Started from the beginning of the 21st century, as the concept of Fourth Industrial Revolution was proposed, it requested more transformative initiatives for both manufacture technology, service, economy and designer education [5]. Meanwhile, the WDO-World Design Organization with former name of ICSID updated the definition of industrial design as: "a strategic problem-solving process that drives innovation, builds business success, and leads to a better quality of life through innovative products, systems, services, and experiences" [6]. For better adapting to above changes in the new era, there are a lot of domestic colleges and universities continuously exploring the optimization and reform schemes relating to the "Industrial Design Engineering" course, and can refine some valuable characteristics shown as below:

According to relevant teaching experience exported from the Industrial Design Department of the Academy of Arts & Design at Tsinghua University [7], it reveals that current teaching contents may be excessively divided into diverse courses due to the complex credit system, but those courses are hard to be linked together effectively. Moreover, limited by the curricular duration and students' concentrate, it should further concern about both of the knowledge learning and skills training may be lack of reasonable depth and systematization. In order to avoid taking more tortuous paths, it suggests the current course scheme relating to the "Industrial Design Engineering" should emphasis on "cultivating high quality of basic knowledge, design and practice skills", which can potentially make up for the lack of professional spirit, design skills and perceptual cognition of contemporary students, and will also be benefit to support the future innovative design development.

At the School of Design, Jiangnan University, the mean points of characteristic teaching in the "Industrial Design Engineering" course are marked as four aspects: 1. Applying big data analysis to assist in determining the target value in the early stages of design; 2. Importing new materials, new processes, or new technologies to promote the innovative product design; 3. Actively exploring the interactional design and relevant technical implementation; 4.

Promoting the user experience design and the service design depend on intelligent technology. Additionally, during the entire teaching process, lecturers should also pay more attentions to cultivate students' logical thinking, analytical and experimental abilities, data analysis and induction abilities, as well as the process management abilities [8].

Refer to relevant experience recorded in the education interview with Professor Haimo Bao at the School of Design, Dalian Minzu University, the syllabus relating to the "Industrial Design Engineering" course precisely encourages students to enhance their self-learning and design skills start from the problem-orientation. Specifically, students should be trained to observe and analyze complicated problems based on systematic and integrated perspectives, and then attempt to come up with the creative design solutions which fully consider internal structures, exterior shapes, material choices and color combinations, etc. The high-level completeness of each product design scheme is finally expected.

In term of theoretical teaching of the "Industrial Design Engineering" course at Nanjing University of the Arts, lots of scattered knowledge relating to engineering principles and applications are refined, sorted and reorganized. Based on an integrated content system, students can study the disciplinary knowledge in step-by-step and achieve gradual upgrading in spiral manner. In the side of practical training, it advocates a theme-centered design practice mode. Under the guidance of lecturers, students should be able to gradually approach the design theme by accumulating open and boundaryless knowledge, and progresses from simplicity to complexity to develop theme solutions and achieve the design applications [9].

Both of Guangzhou Academy of Fine Arts and the College of Art and Design, Jiangsu University of Technology emphasis on developing the teaching and training supported by the "studio system". Over the years, the studios relating to the "Industrial Design Engineering" course insist on guiding students to develop new products with appropriate difficulty and innovative functions or structures. On this basis, it further elevates the teaching and training expectations which encourage students to develop product prototypes with independent intellectual property rights. Meanwhile, mentors of the studio are also encouraged to apply lots of the university-enterprise cooperation projects which can potentially provide more opportunities for promoting the design production to markets [10-11].

At the School of Machinery and Transportation, Southwest Forestry University, the course reform relating to "Industrial Design Engineering" especially emphatic about the importance of practical training, and focuses on cultivating students' handling skill. A characteristic teaching method encouraged by the school is "promoting the efficiencies of knowledge learning and practical training by participating in design competitions". Specifically, in order to win various competitions organized by enterprises, educational departments, and the Ministry of Education, etc. students have to continuously learn leading-edge knowledge and explore innovative applications. Then the competition awards are likely to motivate students to establish positive learning-practicing circulation, which finally promote students to better understand mechanical design, 3D modeling, 3D printing, and processing knowledge and skills [12].

Summarized the relevant experiences of various domestic colleges and universities mentioned in this section, it can easily find that all the theorical teaching and practical training modes generally tend to focus on enhancing students' analytical ability and handling skill. On this basis, lots of characteristic modes such as promoting the research innovation, comprehensive innovation, practical implementation, theme guidance, university-enterprise cooperation, and

competition motivation are proposed or emphasized by different institutions respectively, which can potentially help students to obtain more competitiveness in employment and adaptability to working. While achieving satisfied teaching and training effects, these characteristic modes also inspire other colleges and universities in China to learn and emulate.

However, it needs to remind that the existing course reform information published online are mostly simplified with less implemental details. Moreover, there are no relevant standards for unifying the course credits (involve the credit ratio and time allocation), number & quality of lecturers and students, facility resources, etc. between different domestic colleges and universities. If above characteristic modes are taken out of their original implemental contexts with less consideration of the applicability, it may easily cause a lot of ineffective works and learning burdens for both lecturers and students, which develops far away the basic intention of the course reform. Therefore, based on extensive learning of excellent educational reform experiences, all the developing colleges and universities must reasonably ingrate their actual qualifications, capabilities and multiple-stages exploration experiences to adjust suitable reform modes. In following section, more detailed course development experience relating to the "Industrial Design Engineering" at Fuzhou University will be introduced and explanted.

3 The course development experience of industrial design engineering at Fuzhou University

In order to fully meet the high-level demands of comprehensive development in society, economy, and environment, starting from 2020, the Industrial Design Department at Fuzhou University has updated and clarified the basic goal of the "Industrial Design Engineering" course as: "cultivating talents who can cross integrate cutting-edge (engineering) knowledge and innovative thinking to research and design new products".

3.1 Optimization scheme in term of the theoretic teaching

Guided by above basic goal, the teaching team has comprehensively analyzed the demands of professional discipline construction, the actual teaching qualification, students' knowledge background and learning capability. Then an optimization scheme in term of the theoretical teaching is proposed into four aspects: "Learning Outline" guidance, lecture teamwork, internet resource assistance, and multiple courses integration.

3.1.1 Recommend the "Learning Outline" in teaching mode

Negatively affected by "spoon-feeding" teaching and rote learning modes implemented in traditional classroom context, it finds that most of contemporary undergraduates who study in industrial design specialty tend to passively follow the course requirements, and lack in-depth exploration and individual creativity despite have broad interests [13]. In order to promote and enhance students' autonomous learning abilities, firstly refer to the updated syllabus, teaching scheme, and courseware in each school year, lecturers can sequentially refine and categorize the course knowledge into different difficulty levels, and then establish the knowledge instructional modules and provide the reference lists accordingly for drawing up a clear "Learning Outline" document, which can support students to preview, review and expand professional knowledge independently and efficiently off classes. Then based on sufficient

knowledge, logical thinking, and clear opinions, students can be engaged in specific subject discussions and summarizations fully with self-confidence. Additionally, the "Learning Outline" can also potentially reinforce the positive relevance of the revisions of syllabus, teaching scheme, and courseware to actual teaching works, which is helpful to avoid wasting too many teaching resources only for the educational inspection and evaluation.

3.1.2 Implement the co-teaching mode by lecture teamwork

In the past, under the students' enrollment expansion background, the Industrial Design Department of Fuzhou University ever used to allocate different lecturers to be responsible for teaching the same course in different classes independently, which intended to improve teachers' ability via learning and undertaking more different types of courses. However, due to the differences of teaching experience and knowledge expertise among lecturers, collective evaluation and uniform comparison were usually required to ensure fair assessments across classes. According to the co-teaching experience implemented at Auburn University in the United States and the University of Applied Sciences in Germany, it can be seen that reasonable teamwork between lecturers can effectively avoid the potential bias of teaching experience, and enable students to get more opportunities to communicate with multiple lecturers [14-15]. To be specifically, a senior lecturer and a young lecturer can be arranged to jointly teach multiple classes (generally combine two classes) in one large lecture hall. It allows co-lecturers to undertake different lesson tasks respectively depends on their knowledge expertise, and share the guidance of assignments. The teaching awards relating to class hours are finally distributed to each teacher accordingly. In this way, while ensuring good teaching outcomes, young lecturer can also achieve obvious experience growth without significantly increasing each one's workload.

3.1.3 Develop the network assistant teaching system

Currently, affected by the continuous increase of students' number, most lecturers of domestic colleges and universities start to feel more pressures, such as the overall workload about offline Q&A and assignment evaluations undertaken by every lecturer is obviously increasing, which further results in a relatively reduced amount of guidance time for each student. Additionally, for promoting students with the art background to better adapt and learn industrial design knowledge, the contents of reference textbooks selected by the "Industrial Design Engineering" course tend to be re-edited from complicated to simple year by year [16]. However, till now, the Industrial Design major of Fuzhou University insists on admitting the students with the science background, it causes some feedbacks indicate the updated publications which consists of more elaborate illustrations and simplified explanations of fundamental knowledge are unfriendly to these students' self-study off the classes. Nowadays, as the internet development, for lecturers, there are lots of micro-lessons (1-10 minutes in length) shared online can be sifted to assist the explanations of difficult knowledge. The online teaching auxiliary systems of DingTalk, Tencent, and Yu-Classroom platforms can also help lecturers to improve the processing efficiency of homework assessment and student Q&A work. Moreover, the e-learning mode depended on the internet is appropriate for students to flexibly and freely watch distributed sources of knowledge (such as blogs from design studios and leading academics) without any limitations of physical space and time, which can help students to attain a greater understanding of leading-edge knowledge off the traditional classrooms and reference textbooks [17].

3.1.4 Enhance the cohesion of relevant courses

For meeting upgrading requirements of educational reforms, subject assessments and teaching evaluations, the boundaries of various basic courses have been continuously broken down and restructured for many times in previous years. For example, at Fuzhou University, the courses named “Industrial Design Engineering (A) ” and “Industrial Design Engineering (B)” were transformed from original courses named “Industrial Design Mechanical Foundation” and “Industrial Design Manufacturing Foundation”, Then in a later time, the handling training section included in “Industrial Design Engineering (B)” course was further separated and renamed as “Mechanical Manufacturing Engineering Training” till now. However, along with the continuous planning and adjustment of all the courses, there has been a lack of synchronous communication opportunities among the lecturers, which inevitably causes a certain of knowledge overlap among relevant coursers (as shown in Table 1). In other words, those accumulated knowledge fragments will gradually hinder the coherence and effectiveness of the entire course teaching. Therefore, the lecturers who undertake “Industrial Design Engineering” course also need to pay attention to the efficiency of knowledge connections with other courses, Specifically, browsing of various teaching schemes and courseware can help lecturers to better understand the distribution of knowledge points among courses, and then establishing a knowledge net to guide students to actively link knowledge effectively. This can save more class time for both lecturers and students to expand new knowledge and deal with Q&A, as well as promoting the sense of holistic learning.

Table 1. Similar knowledge fragments exist in different courses

Course Name	Industrial Design Engineering (A)	Industrial Design Engineering (B)
Design Cartography	N/A	Graph reading methods of part and assembly drawings
Engineer Mechanics	Basic analysis and calculation of mechanics	N/A
Model Making	Prototyping and tool selection	N/A
Design Materials and Processes	N/A	Processing and molding technology of metal and plastic products
Manufacturing Engineering Training	N/A	Technical specifications for turning, milling, planing, grinding, and sand casting
Design Management	Product design and development steps and processes	N/A

3.2 Characteristic innovation in term of the practical training

For fully responding to the higher educational requirement which intends to cultivate the application-oriented and innovative designers, while steadily promoting the optimization of above theoretical teaching, Fuzhou University also insists on actively exploring possible opportunities of educational cooperation with enterprises located in surrounding cities. In the first half of 2021, the Department of Industrial Design of Fuzhou University and Fujian Lili Industrial Co., Ltd successfully signed a project called “Research on Popular Toy Product

Design for Promoting the IP Consumption Market Development". The main aim of this project is to establish a long-term cooperation relationship (plans to renew on a 3-year period cycle) between the university and the enterprise depends on existing collaborative education platform. To be more specific, it intends to firstly build a collaborative teaching team which focuses on "Industrial Design Engineering (A)", "Industrial Design Engineering (B)" and other relevant engineering courses. Then around the project theme in term of the toy product design links up with various IP cultural innovations, the team consists of both lecturers and enterprise personnels will share knowledge, experience, resources, facilities, technology, and budget into the classroom teaching and practical training, students are gradually able to learn and understand the entire process involves "conceptual design, drawing revision, appearance confirmation, structural design, handmade sample, mold design, mold manufacturing, technology transfer (from the development department to the production department), production material control, quality control, sales, after-sale services". It ultimately contributes to cultivate industrial designers with excellent professional qualities, proficient engineering skills, and acuminous marketing insights.

After about two years of cooperative exploration, refer to the practical training requirements of relevant engineering courses, above collaborative team totally integrated five categories of control variables: 1. Control design themes (i.e. uniformly set as "contemporary popular toys" theme based on the project planning direction); 2. Control material categories (e.g. PVC sheets, boards, acrylic blocks, sheets, pipes; EVA rolls, etc.); 3. Control mechanical structures (i.e. focus on the planar motion mechanisms); 4. Control sales venues (e.g. sell at the entrance storefronts of Yonghui, Hualian, Carrefour, Walmart, and other large supermarkets); 5. Control price range (e.g. blind box products should be priced below RMB 70, or require the initial batch production costs within RMB 15). In the specific implement process of practical training, corresponding to the open grade, the time period and the depth of knowledge of each course, the categories and quantities of above control variables can be carefully considered for ensuring reasonable training gradient and difficulty (as shown in Table 2). Finally, any extra resource supplement or technical assistances requests will be reasonably evaluated and decided by the dispatched liaison and managers of the enterprise.

Table 2. Practical training innovation relied on the university-enterprise cooperation

Course Name	Year	Practical training Requirements	Restrict Variables	Enterprise Assistance
Design Materials and Processes	2nd	Be able to design some decorative or functional simple products by selecting suitable materials and processing.	1.Design theme 2.Material	• Basic data supply* • Co-guidance** • Design material supply
Industrial Design Engineering (A)	2nd	Selecting appropriate types of mechanism for designing functional product, and analysis and verify the feasibility of mechanism operation.	1.Design theme 3.Structure	• Basic data supply • Co-guidance • Reference samples, power & structural components supply
Industrial	3rd	Proposing and promoting	1.Design	• Basic data supply

Design Engineering (B)		design plan for achieving the harmonization among product appearance, structure, and function.	theme 2.Material 5.Price range	• Co-guidance • Samples supply • Expense reimbursement • Technical assist***
Manufacturing Engineering Training	3rd	Apply appropriate processing and finishing techniques to prototype previous design scheme	1.Design theme 2.Material 5.Price range	• Technical assist • SLA 3D printing service
Graduation Design Practice	4th	Learning how to achieve the commercial transformation from design to production, and assist enterprises to acquire product certification.	1.Design theme 2.Material 4.Sale venue 5.Price range	• Co-guidance • Technical assist • SLA 3D printing service • Expense reimbursement

* Basic data supply: For better supporting the design practice, both teachers and students can be partially authorized to browsing and learning the information data relating to toy marketing analysis, commercial IP database, development intention, technical standards of prototyping, and CMF specifications owned by the enterprise (All the users should promise to protect relevant information away from abuse or leakage).

** Co-guidance: The administrator, designers and technicians from enterprise are welcomed to participate in the design themed lectures and guide the practice workshop.

*** Technical assist: During the practical training, original ideas of structure design proposed by students can be verified by technicians and obtain reasonable modification suggestions. Outstanding design ideas will be further imported into production plan assisted with the enterprise.

Overall, with a focus on the group of courses cored around “Industrial Design Engineering”, the Industrial Design Department of Fuzhou University especially attaches importance to the practical training reform optimized with the “university-enterprise cooperation” characteristic. Based on confirming the specific project development intentions, around the theme of popular toy product design, students are encouraged to actively explore and successfully achieve the commercialization of their conceptual designs. The specific advantages of this reform are summarized as follows:

(1) Compared with most products in other categories, toy products can easier associate with the cultural and visual elements of well-established popular IP, lightweight IP, and even personality-less IP, which can better cater to the diversified emotional needs of the teenage consumer group and evoke their emotional resonance. Therefore, if incorporating this type of theme into the design practical training, since the personal love for popular toys, young students would be more likely to be motivated to actively participate in the proposal creation and practical learning. On this basis, students can be further guided to think comprehensively about the aesthetics, fun, structure/mechanism, materials, colors, craftsmanship, and other aspects of toy products, which is more efficiently to enhance their professionalism, design skills, and sensory cognition.

(2) The primary function of popular toy product is related to promote personal entertainment and relive users’ emotional pressure. Moreover, be benefited from above project

contract, the theme of toy design can also directly access the marketing information updated and shared by the enterprise. In comparison with the proposition design assignments of the functional products in other courses in the Industrial Design specialty (such as the theme of elderly bathroom products or top-notch cabinets are generally appointed by the course named “Comprehensive Innovation”, and the assignment requirements prefer to the functional analysis reports and computer models), during the practical training relating to the toy design assignments, students can appropriately reduce the workloads of preliminary market research, user profiling, SWOT analysis, and so on. Instead, they can invest more time and attentions into the creative expression, prototype design, and physical model fabrication. This can not only highlight the practical characteristics of the “Industrial Design Engineering” course, but can also help achieve the differentiation of theme directions and skill training among various courses. So that students do not feel bored and tired due to continuous engagement in similar assignments.

(3) In the process of jointly guiding the practical training, benefits from long-term communication with the enterprise, lecturers can continuously upgrade their knowledge framework off the theoretical research, and then follow up to correct any cultivate deviations between in-school teaching and social demands. Simultaneously, supported by the complementary experiences of both lecturers and the enterprise, students can receive more comprehensive and impartial evaluations and feedbacks in relation to their design concepts, and the quality of their final assignments can also be significantly enhanced with the technical assistance of the enterprise (as shown in Figure 1). Additionally, in terms of outstanding design works qualified to apply for patents, the enterprise will enjoy the right of first refusal to assign the patent results for commercialization, and will offer appropriate financial remuneration to the students concerned. Ultimately, both the university and the enterprise are able to win the social reputation via news reports online or offline, and it will promote mutual benefits among teaching, learning and production.

Fig. 1. (a) The “Design Materials and Processes” course assignments; (b) The “Industrial Design Engineering (A)” course assignments; (c) The “Industrial Design Engineering (B)” course assignments; (d) The “Graduation Design Practice” assignments supported by the “university-enterprise cooperation”.

In summary, it can be seen that Fuzhou University didn't blindly copy all the course reform experiences from other colleges and universities. Instead, based on the comprehensive analysis of the cultivation characteristics planned by the industrial design specialty, existing teaching condition and various resources (on/off campus) in the Industrial Design Department, in one side, it continuously optimizes the theoretical teaching methods, on the other side, it gradually explores and promotes a practical training innovation with the toy design theme supported by "university-enterprise cooperative education practice" mode. This scheme effectively aligns the substantial content of the teaching reform with the teaching rhythm of this specialty, improves the quality of education and teaching, and promotes the professional development of students with the goal of "cultivating high quality of basic knowledge, design and practice skills". The overall framework of optimizing and innovating the "Industrial Design Engineering" course is demonstrated as shown in Figure 2.

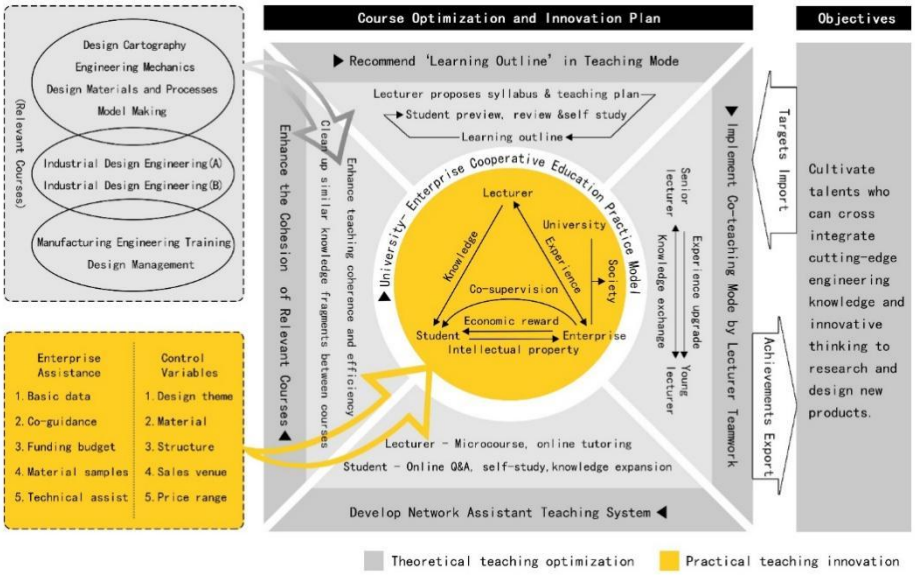

Fig. 2. "Industrial Design Engineering" course optimization and innovation framework

4 Conclusion and Outlook

In the new era, social and economic upgrading brings both opportunity and challenge to China's higher education. In this context, the specialized course construction cored around "Industrial Design Engineering" must be encouraged to explore some more positive reforms, especially enhancing students' basic skills relating to the (engineering) design as well as the capabilities which can percept the transformation and further anticipate the development trend in industrial design domain. Referring to the experience of course optimization and innovation of the Industrial Design Department at Fuzhou University, it recommends that other colleges and universities should firstly propose and improve the basic teaching plan fit to their own actual conditions. On this basis, their practice teaching would be able to yield twice the

achievement with half the effort if integrating more university and social resources to support the collaborative education mechanism establishment. In this way, as the continuous enhancement of students' professional spirit, design skills, and emotional cognition, students can adapt the quick changes of contemporary economic, social and environmental development leisurely, which will be helpful to grasp more employment opportunities and meet upgraded industrial demands and challenges.

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