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A Comparative Case Study of Engineering Competitions between China and the United States*

LIN YUAN** and QING LEI**
Institute of Higher Education, Beihang University, 37 Xueyuan Road, Haidian District, Beijing, China, 100191.
E-mail: yuanlin2017@buaa.edu.cn; leiqing@buaa.edu.cn

Engineering competitions have emerged as challenging and motivating forms of practical educational activities worldwide. However, differences exist in the perception, development and operation of engineering competitions across different cultural contexts. Guided by Activity Theory, this study constructed a basic activity model for engineering competitions, focusing on two dimensions: resource flow and rule constraints. A comparative case study was conducted to examine engineering competitions in China and the United States from a horizontal perspective, considering the two dimensions. The findings reveal shared similarities in the emphasis on engineering design competitions and consistent evaluation factors for similar types of competitions. As for the differences, engineering competitions in China are predominantly driven by national policies, with a primary focus on the electronic information field. Participants and communities prioritize competition results, which has led to a well-established institutionalized resource flow system, high participation rates, and extensive involvement in universities. However, excessive motivation can sometimes lead to utilitarian problems. Conversely, engineering competitions in the United States are primarily driven by engineering professional societies and encompass a broader range of fields. Participants and communities prioritize competition processes, but the attitudes towards engineering competitions vary among universities and competitions. The non-institutionalized resource input may result in unequal access to competition opportunities, especially for financially disadvantaged students. In conclusion, recommendations for optimizing engineering competitions as a tool for enhancing the engineering students' abilities and professional development were given.

Keywords: engineering competition; Activity Theory; engineering education; comparative case study

1. Introduction

Engineering competitions are popular informal educational activities that challenge engineering students worldwide to solve real-world engineering problems or apply engineering design principles. These competitions provide intellectually challenging tasks and competitive learning environments that prepare engineering students for their future careers. Research on the educational effects of engineering competitions primarily focuses on two orientations: one emphasizes on the cultivation of engineering students' abilities and the outcomes of competitions, while the other emphasizes on experiential learning and professional development. These orientations show distinct national differences. Chinese researchers tend to emphasize the role of engineering competitions in developing comprehensive abilities beyond traditional classroom education. These abilities can be categorized into engineering professional skills, such as design, research and development [1], as well as non-technical skills, including innovation, creativity, practical ability, project management, communication and teamwork, and engineering leadership [2–4]. On the other hand, western researchers view engineering competitions as a form of experiential learning, emphasizing their roles in promoting engineering students' professional development, such as self-confidence, sense of accomplishment, interest in professional learning, professional identity, retention rates, and employment rates of engineering careers [7–11]. Exploring the factors underlying these different orientations will help optimize the design of engineering competitions and enhance their educational impact. While existing studies primarily focus on national participants, there is a need for comparative international research that examines engineering competitions themselves. This study adopts a horizontal perspective to conduct a comparative case study of engineering competitions in China and the United States, aiming to uncover the reasons behind the different educational orientations of these competitions.

2. Theoretical Framework

This study constructs a theoretical framework for comparing cases based on Activity Theory. Activity theory is a philosophical framework that explores various forms of human practice [12], with a particular focus on the interplay between activity and consciousness [13]. Based on Engeström's overview of the four generations of Activity Theory [14], this study reviewed the contributions made by the key proponents of the theory (Table 1) to better understand the analysis framework proposed later.

Vygotsky, who first proposed the basic concepts

** Corresponding authors.

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Table 1. Development of Activity Theory

Theoretical schools	"Cultural-historical" Activity Theory		"Work-study" Activity Theory
Academic traditions	Vygotsky-Leontyev-Luria School		Finnish school
Main proponents	Vygotsky	Leont'ev	Engeström
Object	Challenge in individual learning or development	Collective developmental contradictions demanding on expansive solution	From developmental contradictions within and between interconnected activity systems to a critical societal challenge or crisis demanding a multi-level and cross-sectoral solution
Unit of analysis	Mediated action, not activity itself	Collective activity system	From minimally two interacting activity systems with a partially shared object to coalescing cycles of expansive learning in a heterogenous coalition of activities facing a critical societal challenge
Main contributions	Mediation Concept of "S-X-R", also rephrased as Engeström's "Subject-mediating tools-object" triangle	Objective activity; Hierarchical levels of an activity: activity, action and operation; Key elements of collective activities: community, rules and division of labor	Picture Leontiev's activity system as the Structure of Human Activity (including 6 elements and 4 subsystems); Constructed a multi-activity system interaction model with a shared object

Source: Adapted from From mediated actions to heterogenous coalitions: four generations of activity – theoretical studies of work and learning (Engeström, 2021).

of the theory, pointed out that human activities must be mediated by tools (material production tools and socio-cultural tools) [15]. The model of Vygotsky's Activity Theory can be summarized as "Stimuli-Tools-Reactions (S-X-R)" [16, pp. 38–40]. Although Vygotsky acknowledged the significance of activities, he mainly analyzed the foundational conditions for individual-l level advanced mental functions in, not focusing on activities as the primary unit of analysis [17].

Leont'ev shifted the focus of research to a new unit of analysis – the concept of activity, highlighting the importance of objectivity in activity analysis [18, pp. 33–37]. He further expanded the explanatory boundaries of Activity Theory from individual to collective behavior and proposed that internal psychological activity stems from objective practical activities and identified three levels within this framework: activity, action, and operation [18, p. 37]. According to Leont'ev, individuals engage in activities through cooperative interactions, collective activities are motivated by goal-oriented motives, individual actions are driven by goal consciousness, and automatic operations are influenced by the environment and the tools of action [18, pp. 44–54]. Overall, Leont'ev emphasized sociality and objectivity, providing a foundational support for Vygotsky's research on individual actions, such as community, division of labor, and rules. However, Leont'ev did not present a complete conceptual system himself.

Engeström depicted the structure of human activity (Fig. 1) by incorporating elements that inherit the foundational concepts of Activity Theory from Vygotsky and Leont'ev, which broadened the applicability of Activity Theory [19, p. 63]. Engeström's Activity Theory draws inspiration from evolutionary thinking, proposing that human evolution was shaped by individual-environment activities leading to tools, social activities leading to rules, and activities between collectives and the environment leading to the division of labor [19, pp. 59–63]. He emphasizes that no activity exists in isolation; each individual's actions are embedded within a specific social context and relations, with internal contradictions driving change and development [19, pp. 32–33]. While later focusing on intercultural dialogue, Engeström explored relationships between multiple activity systems with shared objectives and applied Activity Theory to address global challenges, expanding its research field from education to workplace learning [20].

The activity structure model comprises three core elements, three mediating elements, and an outcome, which together form four interconnected subsystems: production, consumption, exchange, and distribution [19, p. 63]. The core elements are as follows: (1) Subject refers to the individual or group participating in the activity. The subjects utilizes tools or instruments to bring about changes in the material world and accomplish the objectives of the activity [21]. (2) Object represents the target of the subject's actions. It encompasses the subject's motives and refers to the things in the material world that need to be changed, as well as the expected objectives of the activity [21]. (3) Community refers to the group that shares the object with the subject in the activity [21]. The community collaborates with the subject to achieve the objectives of the activity. The mediating elements are as follows: (1) Tools/instruments are the mediators

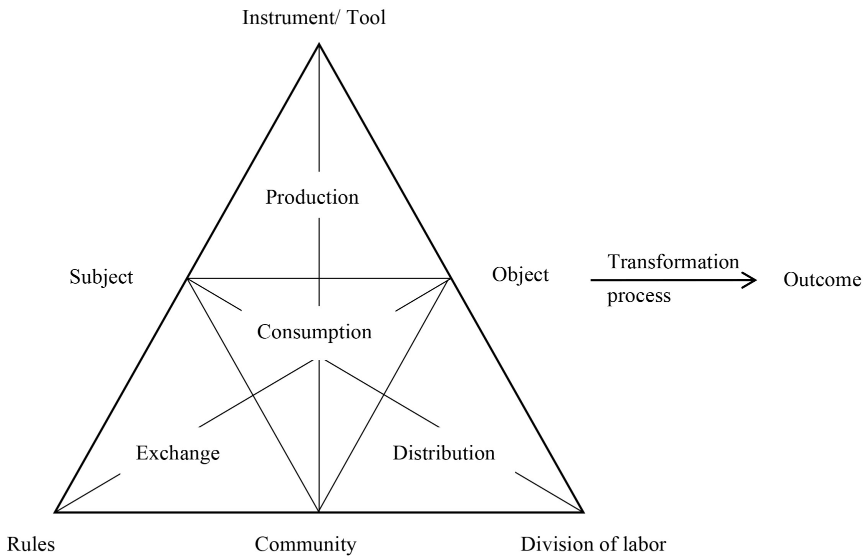

Fig. 1. The Structure of Human Activity. Reprinted from Learning by Expanding (Second Edition): an Activity –Theoretical Approach to Developmental Research (Engeström 2014, p. 63).

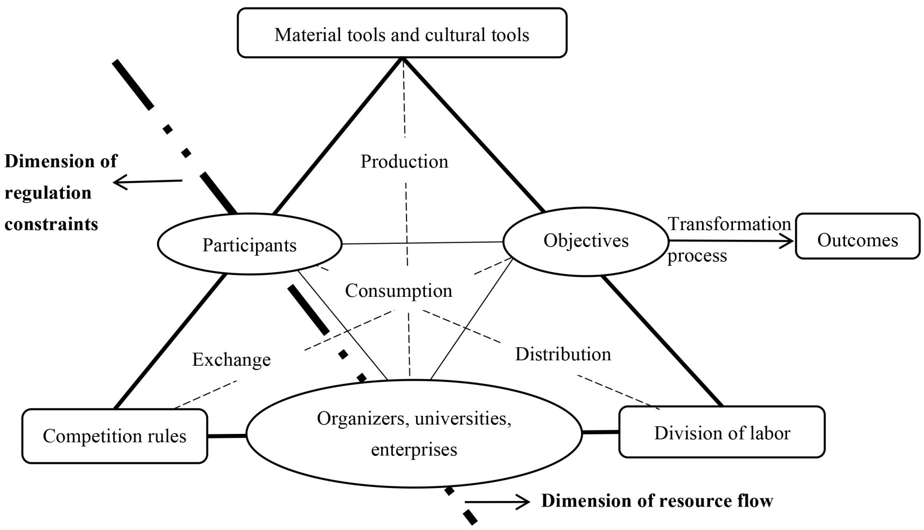

Fig. 2. The Basic Structural Model of Engineering Competitions.

between the subject and the object, referring to any physical or mental things or means that can be used in the activity, such as technical tools, symbols, language, programs, methods, and forms of work organization [21]. (2) Rules are the mediators between the subject and the community, referring to the explicit (implicit) norms, conventions, and social relationships that influence behavior and interaction [21]. (3) Division of labor is the mediator between the community and the object [21]. It refers to the horizontal and vertical division of labor within the community, including the assignment of responsibilities and the power identity [22]. The outcome is independent of the activity and typically refers to additional products resulting from the completed activity.

Engeström used Marx's perspectives to explain the subsystems and their relationships in this model. The production subsystem at the top represents the subject's creation of new products, services, or outcomes through tools to achieve the objectives of the activity. The three subsystems at the bottom support the production subsystem: the consumption subsystem signifies the resource consumption by both the subject and the community during the productive activity; the exchange subsystem indicates that the explicit or implicit rules and social relationships between the subject and the community that influence the smooth operation of the activity; and the distribution subsystem indicates the need to define the responsibilities assumed by different members within the community in the process of achieving the objectives [19, p. 63].

This study utilizes Activity Theory as a descrip-

Table 2. Sample Cases of Engineering Competitions in China and the United States

No.	China	The United States
1	"Challenge Cup" Technological Innovation Competition	AIAA Aircraft Design Competitions
2	National Student Electrician Mathematical Modeling Competition	AGCO National Student Design Competition
3	National Student Intelligent Vehicle Competition	AIChE Chem-E-Car Competition
4	National Collegiate Cyber Defence Competition	AIST Student Project Presentation Contest
5	CCF Big Data & Computing Intelligence Contest	American Solar Challenge
6	University Computer Games Championship & National Computer Games Tournament	ASABE Robotics Competition
7	National Competition of Transport Science and Technology for Students	ASCE National Concrete Canoe Competition
8	National Structure Design Contest for College Students	ASHRAE Student Design Competition
9	The National University Students Intelligent Car Race	DOE Collegiate Wind Competition
10	National Undergraduate Electronics Design Contest	NACE University Student Design and Applied Solutions Competition

tive tool to develop a basic structural model of engineering competitions (Fig. 2). The identified core and mediating elements are as follows: the subject of engineering competition consists of individual participants or teams; the community is the co-participants in the engineering competitions, mainly including the competition organizers, universities, and enterprises; the object entails the competition objectives pursued by both participants and the community through their engagement in the activity; the tools refer to the media used by the participants to participate in the activity, including material resources such as equipment, venues, networks, books, as well as social and cultural tools like personal conditions, peer relationships, and teacher-student relationships; the rules refer to the competition rules that coordinate the interactions between participants and the organizers; the division of labor refers to the distinct roles, responsibilities, and resources provided by organizers, universities, and enterprises to ensure the smooth functioning of the competition.

These aforementioned elements also comprise four subsystems, with this study emphasizing the close relationship between the production, consumption, and distribution subsystems within the engineering competition activity system: in order to achieve their respective competition objectives, organizers, universities, and enterprises undertake specific roles and responsibilities in organizing and operating the competition, which essentially involves providing different forms of resources for both the competition itself and the participants. The participants utilize the resources provided by the community, as well as their own intelligence, energy, and other capabilities, as tools for their participation in the competitions. Evidently, the core essence of the three aforementioned subsystems lies in the flow of resources, which can be collectively examined. However, the fourth subsystem, the exchange subsystem, emphasizes the interpersonal interactions between participants and the community, particularly the constraints imposed by the competition rules established by the organizers, warranting separate discussion.

In summary, this study incorporates the elements and subsystems into the structural model of engineering competitions, categorized into two dimensions: resource flow and rule constraints. It then proceeds to compare the engineering competitions between China and the United States, aiming to investigate the types of competition-based learning environments created for engineering students in the two countries and the factors contributing to the formation of different orientations.

The sources of information used to compare and analyze engineering competitions in China and the United States include literature on engineering competitions in both countries, semi-structured interviews with participants, lists of nationally recognized engineering competitions from selected universities (University of Tennessee, Sichuan University, etc.) in each country (94 competitions in the United States and 51 in China), as well as relevant notices, regulations, and rules obtained from competition websites. We present a selection of sample cases from the numerous engineering competitions utilized in this study in Table 2.

3. Comparison and Analysis of the Engineering Competitions in China and the United States

3.1 Dimension of Resource Flow: Comparison of the Roles and Resource Input of the Communities and Participants

3.1.1 Comparison of Organizers: Differences in the Driving Forces of Engineering Competitions

The organizers play a crucial role in engineering

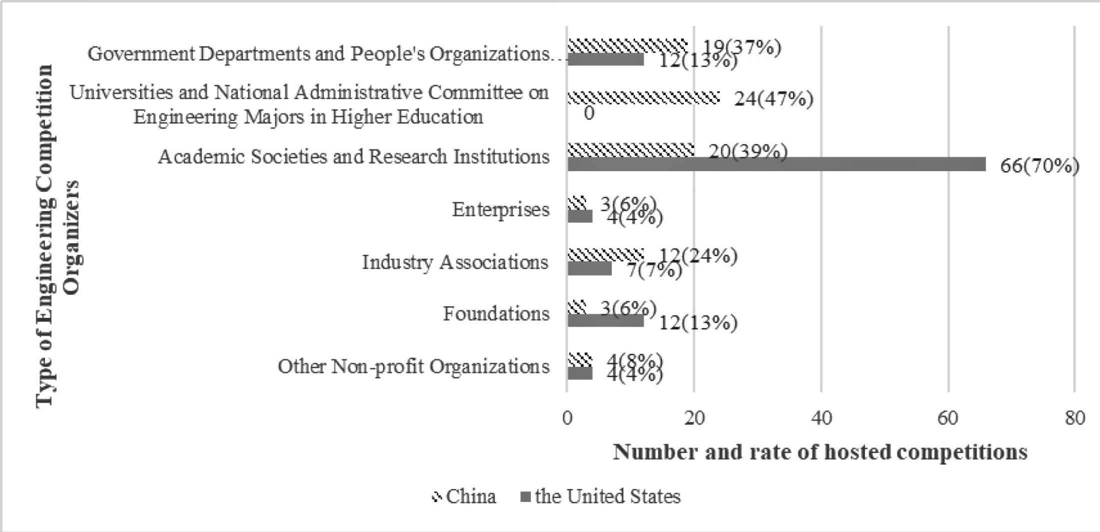

Fig. 3. The Components of Engineering Competition Organizers in China and the United States.

competitions, as they are responsible for deliberating and amending competition regulations and evaluation rules, raising necessary funds for competition organization, evaluation, and rewards, selecting competition venues, establishing evaluation committees and qualification evaluation committees for submitted works. Their efforts lay the foundation for the competition to fulfill its educational purpose. This study analyzed the organizers' composition of engineering competitions in China and the United States (Fig. 3). In the case of the 51 engineering competitions in China, the organizers consisted of universities, the national administrative committee on engineering majors in higher education under the Ministry of Education, academic societies and research institutions, government departments, and people's organizations, accounting for 47%, 39%, and 37% respectively. As for the 94 engineering competitions in the United States, academic societies and research institutions, government departments, and foundations accounted for 70%, 13%, and 13% respectively. These statistics reveal the primary driving forces behind engineering competitions in the two countries. From a broader perspective, there are two main driving forces shaping the nature of engineering competitions in China and the United States.

In China, the development of engineering competitions has been primarily driven by national policies, which have garnered significant attention from various sectors. The quantity, scale, types, organization, and participation in competitions have all been influenced by these policies. The reform of the education system in 1985 expanded the autonomy and management rights of universities. In this context, the first "Challenge Cup" Technological Innovation Competition was held in 1989 by the Central Committee of the Communist Youth League, the Chinese Association for Science and Technology, the Ministry of Education, and the All-China Students' Federation [23]. While this competition did not fully encompass engineering, nearly half of its entries were related to engineering fields such as mechanical and control, information technology, and energy and chemical engineering [24]. The significance of this competition extended beyond its immediate scope, as it served to showcase and lead subsequent competitions. Prior to the year 2000, there were relatively few engineering competitions in China. However, these competitions played a valuable role as teaching aids in traditional and emerging disciplines. In the 21st century, engineering competitions in fields like information technology, automation, and environmental science began to emerge. The implementation of the Undergraduate Teaching Quality and Teaching Reform Project in 2007 marked a peak in the growth rate of engineering competitions in China, followed by a period of relatively stable development [23].

In addition to meeting the needs of higher education and industry development, new competitions have also responded positively to the calls of national policies. For instance, from 2011 to 2015, competitions such as the National College Competition on Internet of Things, the CCF Big Data and Computing Intelligence Competition, and the Big Data Challenge were held in alignment with the emphasis on developing the "Internet of Things" and "Big Data" in national policies. Overall, with the guidance and promotion of national policies, engineering competitions in China have garnered active participation from communities and participants. However, the high level of attention has also led to a strong focus on competition results, considering them as explicit indicators for evaluating student abilities and the teaching quality of universities. This ideological tendency views competitions as activities primarily geared towards ability development.

In the United States, engineering competitions are primarily promoted by engineering professional societies. These societies are dedicated to advancing scientific and technological development and facilitating academic exchanges in their respective fields. They act as intermediaries between industry and universities, and engineering competitions serve as a means for promoting academic competition and exchange [25]. The establishment of engineering professional societies can be traced back to the 19th century when civil engineers played a crucial role in the Westward Movement. In 1852, the first engineering professional society, American Society of Civil Engineers (ASCE) was established. Since then, civil engineering has become the first discipline in the United States [26]. As industrialization and urbanization processes continued, engineering disciplines expanded, leading to the establishment of professional societies in fields such as mining and metallurgy, mechanical engineering, and chemical engineering. These societies further contributed to the professional development of academic careers.

The American Institute of Chemical Engineers (AIChE) Student Design Competition, founded in 1932, served as an early pioneer in national engineering competitions [27]. After World War II, rapid developments in aerospace engineering, radio, electronics, nuclear engineering, materials science, and other fields led to the establishment of related professional societies, which laid the groundwork for more engineering competitions. Academic exchange activities organized by engineering professional societies, such as publications, conferences, and admission of student members, played a significant role in the emergence of early paper and poster competitions. Examples include the Lincoln Arc Welding Awards, the ASME Old Guard Program Oral Competition, the Old Guard Program Poster Competition, and the IEEE Student Paper Contest. In the late 1980s, with the emphasis on "practical" methods in engineering curricula, the Society of Automotive Engineers (SAE International) founded the Baja SAE and Formula SAE in 1978 and 1981, respectively. These were the earliest engineering design competitions in the United States [28]. However, it was not until the end of the Cold War when engineering shifted its focus from military to local development that engineering competitions in the United States experienced rapid growth. The ongoing debate between the scientific and practical orientations of engineering education has influenced the direction of engineering competitions in the country. With the rise of the "Re-engineering" movement in the late 1990s, the American industry market experienced revitalization, and engineering professional societies began establishing numerous engineering design competitions to guide universities in prioritizing and strengthening engineering design education [25]. To this day, engineering design competitions have become the most important type of engineering competition in the United States. Overall, engineering competitions serve as a bridge between industry and universities through the efforts of engineering professional societies. Participants and the community tend to focus more on the long-term impact of participating in competitions on the professional learning and career development of engineering students in their respective fields. Although external motivation may be relatively less and participation rates may be limited, engineering competitions in the United States possess certain advantages in promoting the professional development of engineering students and driving industry advancements in specific fields.

The two driving forces mentioned above not only influence the significance and resource allocation of the community and participants in engineering competitions but also result in differences in the distribution of engineering majors within the competitions between China and the United States (Fig. 4). In terms of quantity, engineering competitions in China encompass 20 professional fields, while those in the United States cover 30 professional fields, showcasing the dynamic nature of engineering professional societies.

Regarding the types of competitions, China's engineering competitions demonstrate a more focused approach in terms of specialties. The competitions that hold a majority in terms of quantity are electronic information (24%), computer (20%), automation (10%), and robot competitions (10%). It is evident that engineering competitions in China predominantly revolve around the field of information technology, with a greater emphasis on electronic circuit design, computer programming, and automation control system design. These areas are closely linked to national key development industries and policy guidance. However, there is a relatively imbalanced distribution of competitions across different professional fields.

In contrast, engineering competitions in the United States are more decentralized and balanced. The competitions that have the highest numbers include aerospace engineering (13%), materials engineering (10%), automation (9%), and mechan-

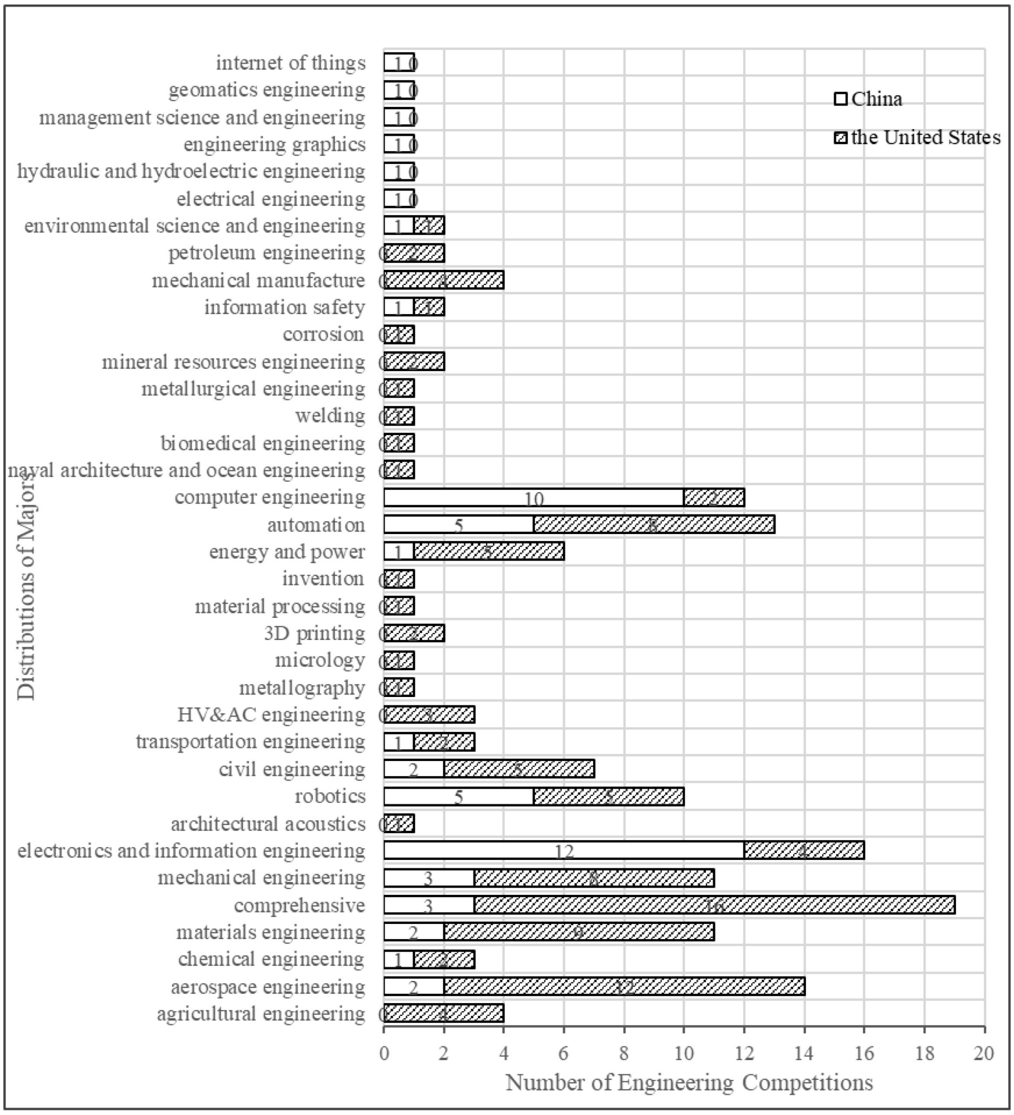

Fig. 4. Distribution of Majors of Engineering Competition in China and the United States.

ical engineering competitions (9%). Unlike China, there is no particular core engineering field that dominates competitions in the United States. Instead, competitions across various specialty areas emphasize engineering design, manufacturing, and control. These differences in the distribution of majors within engineering competitions reflect the varying priorities and emphases of the two countries. In China, the focus is on fields that align with national development goals and policies, while the United States takes a more diverse and comprehensive approach, emphasizing engineering design and key areas within different specialties.

3.1.2 Comparison of Universities: Differences in the Level of Support for Competition Operation

Universities (colleges) play a supportive role in engineering competitions, and both Chinese and American universities allocate resources to provide external support for their participants. However, there are differences in the methods and extent of support, including financial assistance, mentorship, access to facilities, and other resources.

Under the guidance of national policies, Chinese universities actively participate in competition organization and have established well-defined approaches for managing competitions. These approaches include hosting competitions, implementing incentive policies, providing material support, promoting competitions through various channels, facilitating student registration, and offering instructors and training. Notably, two prominent forms of support are evident. Firstly, universities implement competition incentive policies, such as recommending exemptions from entrance exams for master's programs, granting competition-based admission for graduate studies, recognizing innovation and entrepreneurship credits, and factoring competition scores into comprehensive evaluations. While the extent of rewards may vary and occasionally dilute intrinsic learning impact in specific cases due to their utilitarian nature, these policies provide students with appealing external motivation, significantly enhancing their participation. Secondly, Chinese universities generally offer substantial material support to participants, including fund reimbursements, access to skill training platforms, laboratory facilities, and assistance in commercializing winning entries [29]. This ensures that students have the necessary resources and capabilities to overcome the challenges and difficulties encountered in competitions.

Although competition exists among American universities, they generally view the number of awards won by a particular institution as an indication of the level of interest among its teachers and students in the respective competition. However, it is not considered an indicator to evaluate the overall quality of education at the university due to the limited emphasis on competitions. As a result, the organization of competitions in American universities is not as institutionalized, and universities typically do not provide additional incentives for participants. The situation may vary from school to school and competition to competition.

There are two main forms of engineering competitions in American universities: competitions combined with teaching, such as integrating competitions into senior design courses, and pure extracurricular activities through clubs. P. Schuster suggests that the combined format ensures the involvement of senior engineering students who possess the theoretical analysis and design skills suitable for professional-level competitions. However, these students often only experience one project cycle for a competition, resulting in relatively weaker project practice and product manufacturing capabilities [30]. The combined format helps address time management issues and strikes a balance between in-class learning and extracurricular competitions but may also lead to a greater teacher-led role compared to a student-led one [30]. On the other hand, he also suggests that pure extracurricular activities offer more continuity and transferability. Students can participate in multiple competitions throughout their undergraduate careers, continuously honing their practical abilities and gaining a comprehensive understanding of the entire project process. However, the disadvantage of this form is that team sizes are often small and unstable, which can compromise the quality of design work when the team lacks experienced senior students [30]. For instance, Michigan State University provides instructors for all students participating in competitions. The university offers the Waste Management Education and Research Consortium International Design Competition and the ASCE/AISC Steel Bridge Competition to all students. These two competitions are considered foundational to senior design courses, and students have the option to compete for credit as part of the combined competition or participate as an extracurricular activity without receiving credit [31].

3.1.3 Comparison of Enterprises: Differences in the Ways of the Cooperation

In the operation of engineering competitions, enterprises play a crucial role as important partners. They contribute resources in various forms, including direct financial support, donation of equipment or services, and intellectual and human support through providing competition questions and judging entries. Moreover, enterprises leverage these competitions to promote their brand, enhance their image and social influence, and attract talented individuals. While Chinese and American enterprises consume similar forms of resources, there are significant differences in their direct sponsorship of participants.

In China, enterprise sponsorship is primarily invested directly in the competitions themselves rather than in the direct funding of students. Social support from enterprises becomes an integral part of the competition funding, supplementing the financial allocations from education administrations and participation fees [32]. For instance, Beihang Investment Co., Ltd. donated 10 million RMB to Beihang University for the "Challenge Cup" Technological Innovation Competition [33]. However, the sponsorship funds for Chinese participants mainly come from the financial allocations of universities. Many universities have published funding policies for authoritative competitions, requiring second-level colleges to submit annual application forms for funding academic competitions [34]. This increased emphasis on competition awards encourages second-level colleges to actively mobilize students' participation. As a result, engineering competitions in China have witnessed an expansion in participation rates and beneficiary areas.

In contrast, American enterprises may directly sponsor students and provide technical support in addition to sponsoring the competitions themselves. This distinction is linked to the limited resource support provided by American universities to participants. Some club-based teams rely on their own efforts to seek sponsorship in order to successfully complete their competition projects. For example, members of the Baja SAE team at Washington University can apply for funding from the student management department on behalf of the student club, but they also need to personally negotiate with enterprises for financial or material support due to the high costs involved in automotive design and manufacturing competitions. Similarly, a case at Oklahoma State University demonstrates that ChevronPhillips not only provides equipment costs, costumes, awards banquets, and travel expenses for the Chem-E-car Competition but also has staff members available to review participants' safety reports [35]. Through direct sponsorship relationships between enterprises and participants, students develop communication skills, business acumen, and negotiation skills, deepening their understanding of the enterprises. Enterprises, in turn, enhance their brand awareness through participants' competition speeches and presentations. Additionally, enterprises leverage the opportunity to mentor participants and improve their engineering design abilities, establishing employment relationships and indirectly promoting the industry's design standards in the future.

3.1.4 Comparison of Participants: Differences in the Motivation of the Participants

Participants in engineering competitions play a crucial role as they undertake the labor and creative work necessary to complete competition tasks. They must integrate resources from organizers, universities, and enterprises along with their own abilities to succeed. Consequently, the resources consumed by participants in China and the United States are similar. Participants invest their spare time in studying, designing, building, and testing projects. They utilize material, social, and intellectual resources, collaborating with teammates, instructors, and experts to engage in competition learning.

However, there are notable differences between Chinese and American participants. Chinese students often receive more external support and are motivated by both internal and external factors, thanks to the institutionalized resource input and policy incentives. As a result, the participation rate of Chinese engineering students in competitions is relatively high. Some students even participate in the same competition multiple times to continuously refine their skills in a specific area, or engage in multiple competitions to gain diverse experiences and broaden their capabilities.

On the other hand, American participants do not have the same institutionalized competition support system. Their motivation to participate stems more from personal interests and professional development needs. Even in the absence of external support, they exhibit a strong drive to overcome challenges and actively engage in competitions driven by internal motivation. However, competitions in the United States are resource-intensive activities, often requiring significant budgets, faculty mentoring, and specific space and equipment conditions. Due to limited resources, there are issues of unequal participation opportunities and limited benefits for students in engineering competitions. For example, a study examining seven automotive design competitions sponsored by SAE and ASME revealed that although these competitions are theoretically open to all engineering students, structural, cultural, and attitudinal norms limit participation. Analysis of team photos indicated a lack of diversity and fairness, with team members predominantly being white males and female and minority students benefiting less from these opportunities [36].

3.2 Dimension of Rule Constraints: Comparison of the Differences in Competition Rules between China and the United States and Their Effects on Participants

3.2.1 Comparison of Competition Objectives: Result-Oriented or Process-Oriented

The objectives of engineering competitions serve as the initial intentions of the organizers, but their realization ultimately relies on the actions of individual participants. Analyzing the objectives displayed on the official websites of engineering competitions in China and the United States, it becomes apparent that the objectives set by the organizers differ between the two countries. In China, engineering competitions emphasize ability enhancement and multi-level services, while in the United States, the focus is on professional development and industry services.

In China, the objectives of 51 engineering competitions can be categorized into three levels: individual, university, and society. At the individual level, the emphasis is on enhancing students' innovation, practical skills, problem-solving abilities, and communication capabilities. At the university level, the competitions aim to promote curriculum and teaching reforms, improve teaching quality and effectiveness, and contribute to campus culture building. At the social level, the objectives go beyond industry development and encompass responding to national policies and fostering industry-academia collaboration.

In the United States, the objectives of 94 engineering competitions primarily revolve around two levels: individual and industry. At the individual level, the focus is on providing students with experiential learning opportunities, allowing them to engage in engineering design, explore advanced technologies, and provide a platform to showcase and test their research findings or engineering practice experiences. The objectives at the industry level involve deepening students' understanding of specific disciplines, fields, or industries, offering fresh perspectives for solving industry problems through students' creativity and vitality, and cultivating future talents to contribute to industry development.

The objectives of engineering competitions in China and the United States reflect different orientations: collectivism in China and individualism in the United States. In China, competitions carry the expectations of multiple communities, and winning is not only important to students but also a symbol of their abilities and the teaching quality of universities. The emphasis is on the transformational impact of competitions rather than solely the outcomes. On the other hand, in the United States, competitions focus more on the long-term effects on individual professional development rather than the immediate results. For instance, a survey conducted by D. S. Collins on Kettering University alumni who participated in competitions examined the influence of competitions on their learning motivation. The survey found that alumni who actively participated in competitions felt that it had a positive impact on their perceptions and preparation for their careers [37]. The benefits identified by the alumni included building friendships and learning communities, gaining hands-on experience beyond the curriculum, and establishing industry networks [37]. Participating in competitions provided opportunities for communication, learning, and practical application of knowledge, fostering a sense of participation and equal collaboration among team members. These findings highlight the social and personal benefits of engineering competitions in the United States, where the emphasis is on individual growth, networking, and industry recognition. By participating in competitions, students can develop practical skills, expand their professional networks, and enhance their career prospects.

3.2.2 Comparison of Eligibility: Broad or Professional

Eligibility determines the basic issues of who can participate and how to participate in engineering competitions. This study compares the eligibility in the rules of competitions in China and the United States in six dimensions (Table 3).

Firstly, in terms of the academic degree and enrollment status, both China and the United States primarily target full-time undergraduate students for their engineering competitions.

Secondly, in terms of membership and major restrictions, engineering competitions in China generally do not require student membership, except for specific cases where certain institutes may receive preferential participation. In contrast, over 40% of engineering competitions in the United States require participants to be members of the engineering professional society hosting the competition. Additionally, over 50% of engineering competitions in the United States restrict participation to specific majors, whereas only 22% of engineering competitions in China have major restrictions.

Thirdly, in terms of the competition types, both China and the United States have a significant proportion of team competitions, with over 70% in both cases. However, engineering competitions in China tend to encourage interdisciplinary teams more explicitly. The proportion of individual competitions is higher in the United States, which can be attributed to the presence of paper and poster competitions that focus on presenting individual research results.

Finally, in terms of participating units, in China, approximately 33% of engineering competitions

Table 3. Comparison of Eligibility of Engineering Competitions in China and the United States

Eligibility	China	The United States
Academic Degree	Undergraduates mainly	Undergraduates mainly
Enrollment Status	Mainly for full-time students	Mainly for full-time students
Membership	No such requirement, only 1 item mentions that student members will be given priority in the competition under equal conditions	44% required that all/partial participants to be student membership of engineering society
Major Restrictions	22% for specific majors only	53% for specific majors only
Competition types	78% team competition (10% to encourage interdisciplinary teams); 4% individual competition; 18% individual and team competitions are available	73% team competition (2% to encourage interdisciplinary teaming); 17% individual competition; 10% individual and team competitions are available
Participating Units	33% explicitly state that the university is the basic unit of participation, limiting the number of teams per school	1% explicitly state that the university is the basic unit of participation, but in practice also limits the number of teams per school

Source: The data for this table were sourced from official websites and notification information of engineering competitions in both countries, as well as through independent data compilation.

explicitly state that universities are the recommended or basic units of participation. Individual or group applications are not accepted. In the United States, while fewer engineering competitions have such explicit requirements, some competitions still restrict the number of teams per university, even without explicit rules. For example, Baja SAE requires that each university can only register one team, and the team must be recognized by its university. Students lead the entire participation process in Washington University, one member from their Baja SAE team introduced that anyone who is willing to participate could join the team, including non-engineering students. Although their role in engineering design is not significant, they can provide great help in business and marketing. As for the issue of team size limitations in competitions, team members will check the meeting attendance and interview to understand each member's contribution to the team to decide the final list of representatives for the competition. In this way, they prevent excessive competition among members and motivate members to stay active.

3.2.3 Comparison of Competition Types: Both are Mainly Engineering Design Competitions

This study classifies engineering competitions in China and the United States into ten categories based on the types of challenging tasks. These categories are as follows: (1) Engineering design competition: This type of competition involves designing new products, systems, or services, such as electronic design or software design. (2) Simulation competition: In this type of competition, participants simulate and emulate real engineering problems using software. They analyze the simulation results and propose solutions. (3) Research competition: This type of competition mainly gives participants chances to demonstrate their academic research, such as papers or reports. (4) Innovation competition: This type of competition means that participants need to do something new to show their improvement and creativity in engineering. (5) Programming competition: In this type of competition, participants usually write programs to solve problems and compete with others under the same conditions. (6) Experimental competition: This type of competition involves following predefined rules to conduct experiments, collect and analyze experimental data, and write experimental reports. (7) Professional skills competition: Participants in professional skills competitions showcase and compare their knowledge and skills in a specific technical field. (8) Entrepreneurship competition: Entrepreneurship competitions integrate engineering technology and business operations, emphasizing innovative ideas and business acumen. (9) Knowledge competition: These competitions aim to examine participants' mastery of engineering knowledge in specific fields through quizzes, tests, or challenges. (10) Marketing and promotion competition: This category involves the submission of works, such as images and videos, to showcase the application of engineering technology and promote its benefits. Fig. 5 and Fig. 6 depict the distribution of engineering competition types in China and the United States based on the aforementioned criteria, which illustrate that engineering design competitions are the most prevalent type of competition in both countries.

3.2.4 Judging Criteria: Highly Consistent Evaluation Factors in the Same Type of Engineering Competition

China and the United States share four types of engineering competitions: research competitions, simulation competitions, programming competitions, and engineering design competitions. Since similar competitions are more comparable, this study compared the judging criteria of similar competitions and found that the evaluation factors

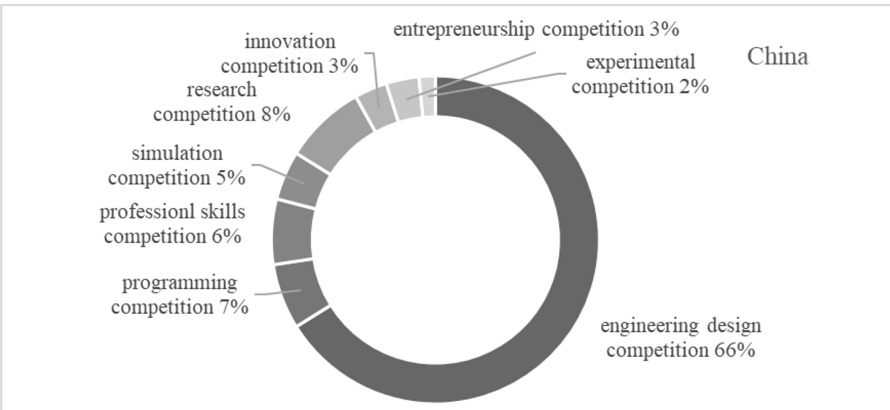

Fig. 5. Distribution of Engineering Competition Types in China.

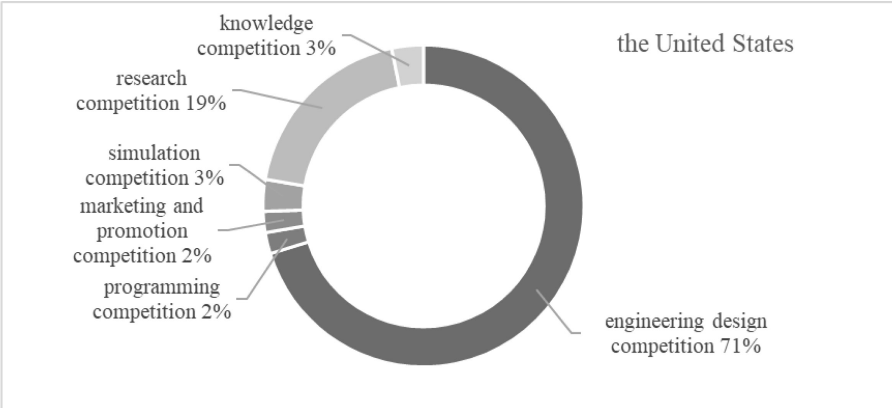

Fig. 6. Distribution of Engineering Competition Types in the United States.

Table 4. The Comparison of Evaluation Factors of Engineering Competitions in China and the United States

Competition Types	Samples in China and the United States	Evaluation Factors
Research Competitions	"Challenge Cup" Technological Innovation Competition	The academic excellence of the work, technical rigor, clarity of objectives, methodology, results validity and reliability, innovation, and the quality of presentations
	ASHRAE HVAC&R Student Paper Competition	
Simulation Competitions	National Student Electrician Mathematical Modeling Competition	The reasonableness of assumptions, innovativeness of the modeling approach, feasibility of the results, clarity of the written text, data processing and analysis abilities, quality of paper presentation, creativity and originality of solutions, and effective teamwork
	ASCE International Contest on Long-Term Pavement Performance Data Analysis	
Programming Competitions	National Collegiate Cyber Defence Competition	Participants' proficiency in programming, their understanding of cybersecurity concepts, their problem-solving abilities in real-world scenarios, and their capacity to maintain system security while meeting business demands
	National Collegiate Information Security Competition	
Engineering Design Competitions	National Student Intelligent Vehicle Competition	The originality and technical feasibility of the design solutions, as well as the performance and functionality of the designed vehicles. Effective communication of design concepts and results is also emphasized
	American Institute of Chemical Engineers (AIChE) Chem-E-Car Competition	

Source: Rules and Regulations of the respective competitions.

of the same type of engineering competition are highly consistent (Table 4).

In terms of evaluating research competitions, the study compares the "Challenge Cup" Technological Innovation Competition in China and the ASHRAE HVAC&R Student Paper Competition in the United States. Both competitions involve several common evaluation criteria, such as paper submission, closed presentation, and public defense. The "Challenge Cup" Technological Innovation Competition in China focuses on the frontiers of academic excellence and scholarship in basic disciplines [38]. It emphasizes the relevance and technical rigor of the paper, clarity in stating objectives, adequacy of the methodology used, validity and reliability of the results, and innovation of the work. Similarly, the ASHRAE HVAC&R Student Paper Competition in the United States also emphasizes the relevance and technical rigor of the paper. It evaluates the clarity of the statement of objectives, adequacy of the methodology, validity and reliability of the results, and the level of innovation demonstrated in the work [39]. Both competitions include closed presentations and public defenses, which evaluate the accuracy of the interpretation of the work, the quality of the presentation, the ability to engage in debates during the defense, and the scientific quality of the text and images presented on the poster. In summary, research competitions in both China and the United States aim to assess the research and presentation skills of engineering students. The evaluation criteria focus on aspects such as the academic excellence of the work, technical rigor, clarity of objectives, methodology, results validity and reliability, innovation, and the quality of presentations.

When comparing the judging criteria of simulation competitions, two examples are considered: the National Student Electrician Mathematical Modeling Competition in China and the ASCE

International Contest on Long-Term Pavement Performance Data Analysis in the United States. In the National Student Electrician Mathematical Modeling Competition, the topics typically come from electrical engineering, modern mathematics, and economic management. These topics are appropriately simplified and processed, covering areas such as information processing, control theory and application, operation and decision making, circuit and electromagnetic field theory, and more. Participants are given 72 hours to complete a paper that includes making assumptions, creating and solving the model, designing and implementing the algorithm on a computer, analyzing and testing the results, and suggesting model improvements. The judging criteria include the reasonableness of assumptions, novelty of the modeling, feasibility of the results, and clarify of the paper. In ASCE International Contest on Long-Term Pavement Performance Data Analysis, participants also need to construct data model, thus the data comes from the real world – a set of pavement performance data spanning 20 years. There are four main evaluation factors: (1) The data processing should be accuracy, complete and reliable. (2) The paper should be structural and well- expressed. (3) The solutions should be innovative and original. (4) Teamwork is also important. In summary, simulation competitions in both China and the United States aim to assess participants' skills in modeling and analysis, problem-solving, and teamwork [40]. The evaluation criteria focus on aspects such as the reasonableness of assumptions, innovativeness of the modeling approach, feasibility of the results, clarity of the written text, data processing and analysis abilities, quality of paper presentation, creativity and originality of solutions, and effective teamwork.

When comparing the judging criteria of programming competitions, the National Collegiate Cyber Defence Competition and the National Collegiate Information Security Competition are considered. The National Collegiate Cyber Defence Competition adopts a "Capture the Flag" system in its practical competition. It covers various topics related to cybersecurity, including web security, binary vulnerability mining and exploitation, reverse analysis and mobile security, cryptanalysis, and secure programming. Participants form teams and are presented with a series of questions, each containing a special string known as a "flag." These questions are designed with different network or application scenarios. Participants must use online operations or offline analysis to obtain the flag embedded in each question and submit the correct flag to earn points. Non-submission or incorrect submission results in no points awarded. Within three hours after the competition, teams are required to submit detailed reports for each question. The National Collegiate Information Security Competition focuses on teams operating the IT system of a virtual company. The objective is to detect external threats and take response measures to ensure the normal operations of the company while facing a simulated system attack by a professional security team. All teams work with the same hardware and software conditions. Evaluation criteria are based on the teams' ability to detect and respond to external threats, maintain the availability of essential services such as mail servers and web servers, handle business requests such as additions or deletions, and strike a balance between security needs and business requirements [41]. In summary, programming competitions in both China and the United States aim to assess participants' programming knowledge and skills, as well as their ability to apply them in solving network-related problems. The evaluation criteria emphasize participants' proficiency in programming, their understanding of cybersecurity concepts, their problem-solving abilities in real-world scenarios, and their capacity to maintain system security while meeting business demands.

When comparing the judging criteria of engineering design competitions, the National Student Intelligent Vehicle Competition and the AIChE Chem-E-Car Competition are considered. In the National Student Intelligent Vehicle Competition, which consists of multiple competition groups, we can focus on the "Intelligent Vision Group" as an example. During the preliminary round, the judging criteria include the innovativeness, technical feasibility, stability, and reliability of the design solutions for the intelligent vehicle chassis, electrical system, intelligent perception, and intelligent control. In the final round, a combination of field tests and technical reports is used. The competition involves tasks such as searching, identifying, and carrying a target panel using the intelligent vehicle model, followed by successfully parking it in the designated garage. The finals incorporate on-site testing and evaluation of the technical reports [42]. In AIChE Chem-E-Car Competition, participants are required to design and construct a chemically powered vehicle. During the poster presentation phase, participants present the power mechanism, braking mechanism, unique features, environmental and safety aspects, vehicle design description, drawings, and test results. They also answer questions from the judges. In the performance test, participants need to design a chemical reaction and determine the appropriate material dosage to ensure the vehicle stops automatically at a specified distance. The absolute value of the distance between the vehicle's front end and the finish line is used for scoring [43]. In summary, engineering design competitions in both China and the United States aim to assess participants' creativity, communication skills, knowledge, technical expertise, innovation, and practicality in engineering design. The evaluation criteria focus on the originality and technical feasibility of the design solutions, as well as the performance and functionality of the designed vehicles. Effective communication of design concepts and results is also emphasized.

4. Discussions

For a considerable period, research on engineering competitions has primarily concentrated on micro-learning activities, especially on "how instructors teach" and "how students learn", while devoting lesser attention to the competitions themselves. However, It is imperative to recognize that the effective implementation of engineering competitions encompasses more than just the participation and efforts of instructors and students. To address the gap, this study adopts a comparative case study method to explore the similarities and differences of the same activity in distinct cultural contexts. Moreover, it examines the development and organization of engineering competitions from a relatively mesoscopic and macroscopic perspective. Our objective is to gain a comprehensive perspective on these events and, in turn, optimize their design, organization, and participation to enhance their educational efficacy.

Limitations of this study arise from two main factors. Firstly, the sheer abundance of engineering competitions makes it impractical to comprehensively encompass all competition items. Thus, we conscientiously utilized a representative sample of competitions recognized by select universities in both countries as the fundamental basis for our analysis, albeit with some data collection gaps. Secondly, divergent education systems, cultural traditions, and social contexts across countries give rise to national disparities in engineering competitions. Although China and the United States serve as prominent exemplars, future research could leverage cross-country comparisons to delve deeper into the distinct characteristics of engineering competitions in diverse regions. Furthermore, enriching the understanding of interconnections between different elements within engineering competitions would enable us to attain a more comprehensive perspective. In spite of these limitations, our study yields invaluable insights into the development and organization of engineering competitions within distinct national contexts, as well as practical suggestions for enhancing and optimizing these competitions. Ultimately, we aspire to contribute to the cultivation of engineering students' professional competencies and foster their overall professional growth through the further exploration of engineering competitions.

5. Conclusions

Engineering competitions play a crucial role in promoting engineering education and nurturing students' practical skills and innovative thinking. Both China and the United States think highly of engineering design competitions, which provide a platform for students to demonstrate their creativity, technical expertise, and problem-solving abilities. The judging criteria for similar competitions in both countries exhibit a high level of consistency, focusing on factors such as innovation, feasibility, technical rigor, and presentation skills. In China, engineering competitions are driven by national policies and enjoy strong support from universities and direct sponsorship from enterprises. These competitions have a collective nature and attract widespread attention. In contrast, the United States promotes engineering competitions through professional societies, covering a wide range of professional fields to cater to students' diverse interests.

Optimizing engineering competitions requires attention to resource allocation and fairness, including providing financial support for students and ensuring equal opportunities for participation, particularly for students in non-popular majors. Moreover, emphasizing the appeal of challenging tasks can foster deep understanding of engineering principles and real-world problem-solving skills. The establishment of specialized competitions in non-popular majors will enable students in these fields to gain practical experience and recognition, encouraging their pursuit of interests and excellence. Encouraging universities to provide institutionalized support for competition organization and management will streamline the process and ensure equal opportunities for all interested students. Diversifying the judging criteria and introducing competitions that cover a wider range of professional fields can enable students to explore different aspects of engineering and develop a comprehensive skill set. Balancing competition results with the learning process is important, by emphasizing the educational value of competitions and providing constructive feedback, students can benefit from continuous improvement and long-term growth. Collaboration with industry partners is also crucial, as it exposes students to real-world engineering challenges and enhances their understanding of industry needs, creating networking opportunities and potential career prospects.

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Lin Yuan, is a doctoral candidate at the Institute of Higher Education of Beihang University. Her research interests lie in the field of higher engineering education and vocational education, with a particular focus on informal learning and self-directed learning. She is passionate about exploring innovative approaches to enhance engineering education and promote lifelong learning in the engineering profession.

Qing Lei, is the Associate Dean, Researcher, and Doctoral Supervisor at the Institute of Higher Education of Beihang University. He holds a Bachelor's degree in Engineering, a Master's degree in Education, and a PhD in Management. His research interests include Engineering Education, Regional Higher Education Development, and Higher Education Institution Management. He is a member of the Academic Development Advisory Committee of the Chinese Higher Education Association. He has also served as a Senior Visiting Scholar at Indiana University and Purdue University in the United States.