

# Operating a Virtual Teaching and Research Section as an Open-Source Community: Practice and Experience

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**Abstract** The teaching and research section is the fundamental organizational unit for teaching and research in a university, and the virtual teaching and research section (VTRS) is crucial for the exploration of the digital transformation of new basic teaching organization construction in the information age. However, this new type of organization transcends institutional and spatial boundaries, and motivating participants and sustaining their engagement are key challenges in VTRS implementation. The VTRS for database courses (VTRS-DB) proposes an open community-based operating model, founded on the core concepts of openness, dedication, competition, and orderliness. It establishes a hierarchical organizational structure and working group operation mechanism. After two years of practical exploration, a course knowledge graph and a wealth of teaching experiment cases have been developed. A series of distinctive teaching and research methods, such as collaborative course preparation, have been implemented, and the domestic database in the classroom brand activity has been established. The VTRS-DB has incubated several national and provincial level first-class courses and has won national and provincial level teaching achievement awards, achieving significant results.

**Keywords** virtual teaching and research section, database course, open-source community, collaborative teaching and research

## 1 Introduction

The teaching and research section (TRS) is a fundamental teaching unit established within colleges

and universities and organized by majors and courses. Its primary responsibilities include implementing teaching plans, compiling teaching materials, formulating teaching syllabi, preparing teaching calendars, and researching and improving teaching work (Song, 2020; Wang et al., 2022; Zhang et al., 2023). However, the rapid advancement of digital technologies, including the Internet, Big Data, and AI, has propelled society into the digital age. As a result, the learning methods, learning contents, learning abilities, and learning forms of college students are evolving at an accelerated pace, rendering traditional TRS largely obsolete. The digital development of higher education has become a critical strategic issue that significantly impacts and determines the high-quality development of higher education. As a manifestation of exploring digital transformation, in 2022, the Ministry of Education of the People's Republic of China (MOE) announced a list of pilot projects for the construction of the virtual teaching and research section (VTRS) (Sang et al., 2021).

As a new exploration, VTRS still has limitations and faces a series of challenges. First, the VTRS is based on the functions and organizational innovations of TRS in universities, VTRS transforms courses offered by outstanding teacher teams into open online courses. Through cross-temporal co-construction and sharing, it creates VTRS across universities, shares teaching resources, improves teaching platforms and learning tools, and cultivates creative learning abilities of both teachers and students. This innovative form of organization not only inherits the characteristics of traditional TRS but also embodies a new form of collaborative teaching and research based on information technology. It is also an innovative grassroots teaching organization (Lu & Zhang, 2018).

Second, the VTRS is a cooperative community for cross-border learning, a spiritual community governed by contracts, and a practical community that leverages complementary advantages. It is a collective composed of discipline experts, teachers, technical

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departments, and participating units, all dedicated to enhancing teacher instruction and talent cultivation. The essence of VTRS is a cross-border teaching community with a cooperative teaching survival pattern, which embodies the concept of spatiotemporal aggregation, enabling teacher sharing and cooperating to transcend geographical, regional, and disciplinary boundaries, thereby meeting needs of teaching development.

Third, the operation mechanism of VTRS remains influenced by traditional TRS implementation, prioritizing activity organization over member initiative and emphasizing the management of members rather than valuing cooperation. It focuses on institutions with cooperative relationships, neglecting cross-university, cross-disciplinary, and cross-regional exchanges. As a result, mechanism construction fails to break through path dependence, thereby limiting VTRS coverage (Meng et al., 2023).

Fourth, the VTRS has yet to develop an effective mechanism for mutual assistance among members, joint construction and sharing of resources, and outcomes accumulation and promotion. While collaborative teaching platforms for student groups, such as massive open online courses (MOOCs), have matured and collaborative teaching and research platforms for teacher teams remain underexplored. Teaching and research still rely on the transmission, guidance, and leadership between new and experienced educators. The utilization of digital resources, and the transformation and accumulation of teaching and research outcomes are not fully leveraged. Moreover, there is a gap in supporting digital fundamental platforms, which hinders the growth potential of VTRS (Zhang, 2023).

Fifth, the imperfect mechanism of joint construction and sharing leads to inactive participation, failure to establish social reputation mechanism, and the pending honor system for member growth. Moreover, the projects to establish active communities are not diverse. Teachers in charge generally require ability improvement and seek honors, rewards, and career promotion. However, the VTRS lacks administrative affiliation among members, resulting in participants being scattered across units and regions, and is void of face-to-face interaction. Therefore, motivating, maintaining, and guiding participation behavior are crucial challenges in operating VTRS.

Addressing the above challenges, the VTRS for database courses (VTRS-DB) proposes an open community model for operating VTRS, guided by the principles of openness, dedication, competition, and orderliness. The VTRS-DB aims at facilitating a transition from individual to collaborative efforts, empowering each teacher to be an active contributor. Under this mechanism, teachers will continuously

enhance their collaborative competence. The VTRS-DB has established a sound organizational structure and operating mechanism, attracting over 200 teachers and database developers from more than 100 universities and enterprises to join. The VTRS-DB has hosted over 100 teaching and research activities and built 4 major teaching resource databases, including course knowledge graphs (KGs). Notably, the VTRS-DB has incubated a number of national and provincial level first-class courses and teaching achievement awards.

## 2 Construction of VTRS

Initiated by Renmin University of China (RUC), the VTRS-DB consists of institutions, such as Tsinghua University, Northeastern University, Shandong University, and 11 other institutions, as well as Huawei Technologies Co., Ltd. The VTRS-DB operates under the framework of the previously established intercollegiate cooperation group for database courses, adopting an open-source software community model to facilitate resource joint construction and sharing. The primary goal of the VTRS-DB is to focus on database-related courses, with a focus on deepening reforms in course contents, teaching methods, teaching resources, and assessment. Guided by the ideology of stratified teaching, the VTRS-DB constructs KGs, develops teaching materials and lesson plans, emphasizes practical teaching, and extends subject competitions. Its ultimate aim is to innovate teaching and research formats, enhance teaching exchanges, and build high-quality resources collaboratively.

### 2.1 | Following the Guidance of Stratified Teaching

Digital transformation is crucial, and the VTRS is a vital component of this process. It transcends institutional and spatial boundaries, laying the groundwork for more extensive and stratified instruction (Chen & Xie, 2023; Hong, 2016). Students are in development with factual disparities. In actual teaching practice, a stratified instruction is often employed (Filius et al., 2018; Zhang et al., 2023). There are over 3,000 colleges and universities in China, with more than 1,300 undergraduate institutions. These institutions exhibit obvious hierarchical differences in orientations and goals. A few institutions focus on cultivating research personnel, while most focus on developing application-oriented talents (Tan et al., 2022). At each level, there are numerous similar institutions, and students' stratification is also similar. Teachers in traditional TRS implement differentiated education within a single university based on student performances, such as setting up top notch classes and undergraduate–master

integrated classes. The emergence of VTRS provides a better communicative platform for differentiated education, allowing teachers from different institutions to learn from each other. Furthermore, the VTRS collects more accurate information, laying a solid foundation for top-level design of differentiated teaching in institutions.

The VTRS-DB has established several working groups to categorize database teaching syllabus for universities at varying levels. The syllabus encompasses KGs, class hours, experimental practices, reference books, teaching requirements, key points, and difficulties of each chapter. Based on current situation of Chinese universities, we have compiled three versions of syllabi corresponding to the universities and disciplines included in the “double world-class project”, top research institutions, and a broader range of applied universities. According to the syllabus content, teaching contents for universities included in the “double world-class project” generally implement database kernel, while the syllabus content for research universities focuses on how to utilize the database. In contrast, the syllabus content for applied universities features reduced theoretical components and increased emphasis on practical operations. Through arrangement of the syllabus, VTRS can further discuss how to design tiered teaching plans for universities at different levels.

With the assistance of VTRS platform, teachers can share tiered teaching plans and methods, and engage in discussions. The VTRS-DB has organized five preparing a class together activities, which have been accompanied by a series of teaching and research activities for courses with stratification, attracting more than 400 participants. The themes of these activities include how to effectively explain specific knowledge points and how to implement heuristic teaching in database courses. Speakers are from renowned research universities and application-oriented universities. Through these special preparing a class together activities, teachers can gain deeper insights into how other institutions implement database teaching, particularly those at different educational levels.

## 2.2 | Starting with KG Construction

KG is a visual representation or map of knowledge that illustrates developmental processes and structural relationships of knowledge units. It utilizes visualized techniques to describe knowledge resources and their carriers, and to mine, analyze, build, draw, and present knowledge and their interrelationship. KG can help teachers to better understand connections among different knowledge points, thereby designing more scientific and reasonable teaching plans (Chen & Xie, 2023).

The VTRS-DB has conducted a comprehensive

survey of the courses and textbooks of more than 50 top universities worldwide and summarized three levels of database course teaching objectives, including database bases, database principles, and database systems. Database base courses primarily cater to non-computer science students, cultivating their abilities to use structured query language (SQL) proficiently. Database principle courses are primarily for computer science students, cultivating their abilities to master database application development and administration. Database system courses is also catering to computer science students, enhancing their competence to develop kernel components of database system.

According to the teaching objectives, KG of database courses has been constructed. The KG consists of five modules, including database system bases, database designs and development, database system principles, database system kernel implementation technologies, and innovative technologies, with 75 knowledge points in total. With KG as a starting point, teaching plans, exercises, courseware, experiments, and other resources of the database courses have been constructed according to knowledge points.

The database is a crucial system software within a wide range of applications and plays a vital role in various industries. Moreover, the industry has advanced and mature technologies at its disposal. The KG database construction incorporates leading enterprise technologies, with KG as a foundation, facilitating the integration of industry and education. By promoting the deep integration of industrial development and talent cultivation, the adaptability and competitiveness in the market can be enhanced. The organic chain among education, talent, industry, and innovation can be established to meet the industrial high-quality development needs.

With the support of *Intelligent Campus 2030* (Huawei, 2024), the course introduces the pioneering technology of Huawei’s openGauss database in KG. For example, the non-uniform memory architecture of Kunpeng 920 is introduced to show how to improve processing performance of Huawei’s openGauss database on the Kunpeng platform. Moreover, AI-optimized models and cardinality estimation techniques based on lightweight models are introduced. These innovations enable students to gradually understand, master, and proficiently use the openGauss open-source database. In the final new technologies modules, Huawei Cloud GaussDB, a fully encrypted database, is introduced, allowing students to comprehend current solutions of privacy protection throughout the entire life cycle.

## 2.3 | Focusing on Textbooks and Teaching Plans

First, textbooks are crucial tools during instruction,

serving as guidelines and references for organizing teaching activities (Zeng et al., 2020). An excellent textbook not only enables teachers to quickly and effectively impart knowledge but also fosters students' self-learning, critical thinking, and innovation skills. In 1983, RUC published a classic textbook *Introduction to database systems* by Professors Shixuan Sa and Shan Wang, which primarily focuses on teaching how to utilize databases (Wang & Sa, 2014).

To enable students to not only master fundamental concepts of databases, basic knowledge of SQL, and basic principles of database management systems (DBMSs) but also to design and implement a small DBMS system, Professor Xiaoyong Du et al. (2024) from RUC published *Principles and implementation of database management systems*, and Professor Guoliang Li et al. (2024), members of the VTRS-DB, published *Database management systems: From basic principles to system construction*. These two textbooks focus on the design and implementation techniques of core components of DBMS, systematically introducing the basic concepts of database, SQL, fundamental principles of DBMS, and implementation techniques. The books emphasize different aspects of depth, breadth, and training systems, and outline the knowledge system of three major components of databases, including storage management, query processing, and transaction management. They establish core structures students should master while reinforcing practice, and they help students to understand current technological trends from a future-oriented perspective. The content of textbooks is divided into four major knowledge modules, including fundamentals of DBMSs, principles of Relational Database Management Systems (RDBMSs), database kernel implementation, and new database technologies. The fundamentals of DBMSs module includes four knowledge points, including database overview, relational data model, SQL, and advanced SQL. The principles of RDBMSs module include four categories of knowledge points, including query processing and optimizing, transaction managing, concurrency controlling, and fault recovering. The database kernel implementation module helps students to understand how to build an RDBMS from scratch, or how core database components work in mainstream RDBMS. This module includes knowledge points on storage managing, indexing, query processing and optimizing, engines executing, concurrency algorithms controlling, and algorithms recovering. The new technologies module helps students to learn about current cutting-edge academic technologies within three categories, including new models, architectures, and applications of database systems.

Second, teaching plans outline instructing

ideas, methods, and outcomes. They enable instructors to organize teaching contents logically, enhance the specificity and adaptability, facilitate teaching evaluation and reflection, and elevate teaching quality and effectiveness. Moreover, teaching plans serve as foundation for evaluating instructing performance.

In the context of developing lesson plan, the VTRS-DB has conducted a course content survey, selecting 6 universities included in the "double world-class project", 5 excellent research universities, and 30 applied universities. Through questionnaires, the organization has gathered and summarized the teaching challenges of database courses and arranged various knowledge modules and points, thereby providing guidance for discussion of teaching methods and lesson plan design.

The VTRS-DB has pioneered an innovative method for sharing key and challenging course concepts and establishing a comprehensive case library. Leveraging the course KG, VTRS has developed a range of resources, including training programs, syllabi, KGs, teaching videos, electronic courseware, exercises, test questions, instructional cases, experimental projects, and practical training projects. Moreover, VTRS has researched the co-creating and sharing of educational resources. In 2023, a national database course lesson plan competition was launched, inviting instructors to participate in. The expert panel in the related fields have reviewed the submissions and selected the most outstanding plans through the scoring system. The awarded plans have been incorporated into an excellent lesson plan library and recommended for publication in the related journals. Based on this, instruction seminars have been organized, featuring award-winning teachers and renowned database teaching experts who have presented and thoroughly analyzed outstanding cases.

## 2.4 | Rooting in Course Experiments

Theoretical learning cannot be separated from practice. However, developing a database from scratch can be labor-intensive, often presenting unexpected anomalies and errors during the developing process, which may daunt students. To apply the knowledge learned in class to kernel development and appreciate the importance of DBMSs as a fundamental software, the VTRS-DB has spearheaded the development of a database prototype system framework called RucBase, comprising approximately 15,000 lines of code. The RucBase includes all the essential components of a DBMS and can run standard database benchmarks.

In line with the goal of cultivating the ability to create a database, the VTRS-DB research group have mapped knowledge points to the code in RucBase, thereby enabling students to conduct four major laboratory experiments where they fill in blanks

according to experiment requirements. The laboratory provides test cases to automatically evaluate knowledge points. Students can ultimately create a complete DBMS by completing these experiments. We assist students gradually overcome their apprehensions through breaking down complex problems, writing innovative textbooks, building an experimental platform, and establishing academic competitions.

The RucBase is an educational database open laboratory on GitHub and it has been successfully demonstrated and applied at four prestigious universities, including Xidian University, Harbin Institute of Technology, Huazhong University of Science and Technology, and RUC. Approximately 500 students utilize the platform annually, with each student contributing an average of 2,000 lines of code, ultimately achieving the goal of creating a comprehensive database.

The VTRS-DB has explored the deepening of cooperation between universities and enterprises, conducting practical teaching, internship, and training to enhance students' skills in real world, thereby improving their employability and innovation and entrepreneurship capabilities. By establishing a researching and training platform, creating a two-way development mechanism, facilitating cross-disciplinary and cross-regional exchanges, and inviting external mentors, the VTRS-DB promotes diverse cultivation, varied development, and multi-channel implementation, fostering the deep integration of resources inside and outside the institutional system.

Enterprise technology is seamlessly integrated into the course experiment and training platform, resulting in the development of an experimental case library. This has led to creating a research report and a recommended catalog for laboratory training platforms, which are subsequently promoted. Within the VTRS-DB teaching design process, enterprise platforms are utilized as experimental training platforms for cultivating innovative talents familiar with technological ecosystem of enterprises. By addressing the gap between educational goals of university courses and enterprise needs, the VTRS-DB invites companies to participate in teaching practices, exploring interactive teaching models between universities and enterprises. This initiative brings enterprises into campus and classroom, providing robust resources and technical supports for education and talent development. To achieve this goal, the VTRS-DB has collaborated with domestic vendors, organizing a series of domestic database in the classroom activities, which involves nearly 100 university database teachers and domestic database enterprise technicians. This initiative connects teachers with engineers and further promoted industry–education integration through ongoing exchanges and cooperation beyond classroom.

## 2.5 | Extending Through Subject Competitions

In the reform of higher education teaching, cultivating high-quality innovative talents with a spirit of innovative and practical competence is a crucial task for universities. With the MOE explicitly incorporating subject competitions into the reform of practical instruction and talent cultivation models, these competitions have become vital components of talent development in institutions. By integrating competition-based education with traditional education, thereby making competitions the extension of student learning, it is possible to foster scientific thinking, innovative awareness, and cooperative competence. Compared with traditional education, competition-based education emphasizes the practice and the evaluation of experimental outcomes (Sun et al., 2023).

The VTRS-DB organized the database track of Computer System Development Capability Competition, which aims at equipping undergraduates with the ability to build databases. Based on RucBase, we developed the Renmin Database (RMDB), which provides students with a database kernel framework. Students build upon the RMDB to implement function logic, ultimately constructing a complete database system kernel. The competition is about not only building a database but also developing a better one, requiring teams to optimize their implementation techniques as much as possible, fostering a spirit of excellence and craftsmanship. The inaugural competition has attracted 381 teams, comprising 998 participants from 26 provinces and municipalities, and 89 universities, including 28 universities included in the “double world-class project.” Among the outstanding entries, some could run transaction processing council benchmark C (TPC-C) and achieve industrial database standards, thereby achieving the goal of contributing to cultivate database kernel talents in China.

The VTRS-DB has facilitated the establishment of Kunpeng group for the China International College Students' Innovation Competition (2023). It leads the formulation of 19 questions across four categories in the openEuler and openGauss. The VTRS-DB has organized students to participate in the competition in conjunction with its own course knowledge. The overall team of VTRS-DB has recorded contributions from VTRS-DB members in terms of registered teams, participated teams, and teams advancing to the finals. These contributions serve as important references for evaluating and recognizing VTRS-DB members and providing incentives for the operation of VTRS-DB.

## 3 Operational Models of VTRS-DB

The successful operation of VTRS-DB relies heavily on

engaging all participants in the discussion on the topics they interest. Therefore, motivating participants and sustaining their involvement are crucial. To address this, the VTRS-DB has proposed an open community model guided by the principles of openness, dedication, competition, and orderliness. The VTRS-DB welcomes all participants with an open attitude, fosters a spirit of dedication for mutual construction and benefit, utilizes a competitive mechanism to motivate participation and recognize contributions, and operates the VTRS-DB orderly based on open-source community rules.

### 3.1 | Core Principles of Open-Source VTRS

The core principles of open-source VTRS are rooted in the values of transparency, collaboration, and community-driven development. These principles are essential in fostering innovation, flexibility, and continuous improvement, which are critical to the success of open-source VTRS.

Open-source community operations typically comprise core elements, such as mission, rules, and product incentives (Jiao & Yang, 2022). VTRS drew inspiration from open-source communities, defined core elements, and established guiding principles to maintain stability and activity. The VTRS-DB has developed its operations based on eight core elements, including noble mission, transparent rules, democratic decision-making, clear products and goals, rich activities, social reputation, incentives for participation, and sustained supports.

Firstly, establishing the VTRS requires having a sense of noble mission. VTRS must have a clear mission to inspire members to actively join. Teachers in the VTRS are expected to focus on moral education, improve talent cultivation capabilities, enhance their digital literacy, and contribute to instruction through collaborative development, thereby supporting high-quality development of higher education.

Secondly, the rules of VTRS are transparent, straightforward, and grounded in the principles of openness, dedication, competition, and orderliness. The emphasis on open participation fosters collaborative teaching and research projects that are free, open, standardized, and well designed, focusing on knowledge contributions. VTRS also establishes a stratified and grouped working mechanism, featuring mechanisms for appraising and dynamic facilitation based on participation.

Thirdly, establishing VTRS needs democratic decision-making process which means that what VTRS will and will not do are made through a democratic process. VTRS has established a hierarchical organizational structure, comprising committees, working groups, formal members, and observers. The

democratic decision-making process also requires to operate with a mechanism of proposals, discussions, implementation, and documentation of results.

Fourthly, to establish VTRS, the open-source communities need clear goals. VTRS must provide transparency regarding its outputs, how members contribute, and the benefits VTRS achieves. VTRS-DB's products are the database courses, which are categorized into four distinct types: first, textbooks and reference materials, which addresses what to teach; second, teaching process designs and PowerPoint presentations, which addresses how to teach; third, experimental designs and academic competitions, which addresses how to practice; fourth, test questions and question bank construction, which addresses how to assess.

Fifthly, VTRS-DB is expected to include rich activities. To support the community's operation, it is essential to have a diverse range of activities aligned with the core mission. Organizing and conducting activities are crucial for maintaining stability and engagement. VTRS has established several groups to carry out specific tasks with defined goals and regularly publishes updates on office activities to enhance participants' understanding and communication.

Sixthly, social reputation is crucial for the vibrancy of open-source communities, as it reflects peer recognition. Reputation is often represented by stars, likes, and download times, which indicate the popularity. A set of effective mechanisms for gaining community recognition is essential, and forming a positive social reputation for participating teachers is key to addressing.

Seventhly, participating in the VTRS-DB needs different roles and purposes for incentives for participation. Teachers primarily seek autonomy in exploring and innovating teaching methods and are generally motivated by professional development, recognition, rewards, and promotion opportunities. Moreover, engineers focus on enhancing their innovation capabilities and promoting eco-friendly products.

Eighthly, sustained support is needed in establishing VTRS-DB. The VTRS-DB, as part of Huawei's intelligent base, leverages corporate support and integrates ecosystem features across course resources, practical platforms, textbooks, MOOCs, and competitions, thereby driving the operation of VTRS through industry-education integration.

### 3.2 | Operational Mechanism of the Open-Source Model VTRS

The operational mechanism of the open-source model, VTRS is as follows. The construction of VTRS is led by institutions, with enterprises providing support for

their activities. A hierarchical organizational structure is established within the VTRS-DB, comprising a steering committee, working groups, regular members, and observers. This structure facilitates effective collaboration and decision-making. The working mechanism to operate working groups involves a proposal process, committee discussion, group implementation, and uploading teaching outcomes. Explorations are conducted on various aspects of teaching and research methods, including course construction, teaching materials, curriculum discussion, experimental practice, and model improvement. Moreover, enterprises provide support in areas, such as cooperative course development, faculty training, and teaching assistant classes. The organizational mechanism of open-source VTRS is depicted in Figure 1. The steering committee serves as the core institution of TRS and comprises all core members. The committee typically holds a meeting monthly to discuss and decide on important matters related to teaching and research activities.

The working group is responsible for fundamental tasks of TRS, with each group having clearly elaborated tasks. Each group is led by a group leader and several deputy leaders. The leaders of a working group are appointed by regular members, with the appointment being discussed and confirmed by the steering committee. Members of the laboratory can participate in internal seminars and working groups. They can also take an active part in curriculum development. Teachers who give related courses and all research and development personnel, can submit applications to become regular members of the laboratory, with the appointment being discussed and confirmed by the committee. Furthermore, there are observers who do not need to apply but can participate in all open activities organized by laboratory and obtain

all open resources. Teachers who instruct related courses and all developers can become observers.

The VTRS-DB’s daily work is carried out through the working groups. First, committee discusses tasks requirements, deadlines, and outputs and assigns them to the working group. Second, the working group discusses tasks internally and organizes a dedicated team to take on the specific assignment. The working group is also responsible for ensuring the quality of the work and the materials uploaded by its members. Third, the working group reports to the committee on the progress of tasks, which is then deliberated on by committee. The working group operation mechanism is depicted in Figure 2.

## 4 VTRS-DB Construction Achievements

The evaluation of VTRS can be conducted across five dimensions, including individual development, intra-organizational cohesion, task-driven objectives, organizational structures, and educational research activities (Cao, 2024; Wu, 2016). This chapter focuses on these five aspects and presents the achievements attained by the VTRS-DB.

The first assessing dimension is individual development. Over the past two years, numerous young faculty members in the VTRS-DB have achieved commendable results, including 1 national first-class course, 13 national or provincial teaching awards, and 4 new textbooks.

The second dimension is intra-organizational cohesion. The VTRS-DB has successfully attracted 180-member units spanning 28 provinces and municipalities, with a total of 312 members. To date,

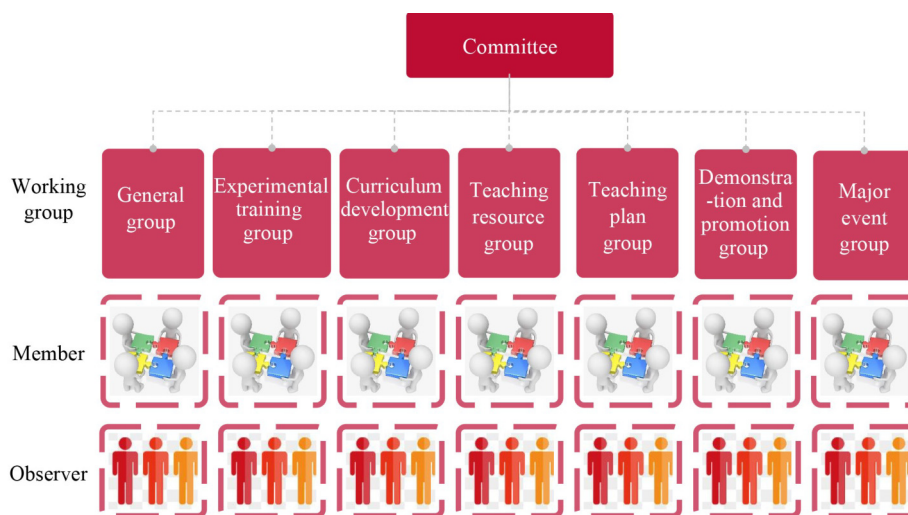


Figure 1 Organizational mechanism of open-source VTRS. VTRS: virtual teaching and research section.



**Figure 2** Working group operation mechanism of open-source VTRS. VTRS: virtual teaching and research section.

the organization has held three annual general meetings, each of which has drawn more than 100 members in attendance.

The third dimension is task-driven objectives. As depicted in Figure 1, the VTRS-DB employs a working-group mechanism, wherein each group is equipped with clear objectives, task lists, and definitive timelines. These task-driven mechanisms ensure that the VTRS-DB remains consistently vibrant and dynamic.

The fourth dimension is organizational structures. The VTRS-DB has established ten working groups, with more than half of its members actively participating in these groups. Among these ten working groups, two have been specifically set up to cater to colleges and universities in remote areas, namely Ningxia working group and Inner Mongolia working group. The VTRS-DB aims at enhancing instructors' teaching and research capabilities in the western regional institutions through the two working groups.

The fifth dimension is educational research activities. We have conducted over 340 online and offline teaching and research activities centered on curriculum contents, teaching resources, and teaching promotion, thereby constructing a wealth of instructional materials.

In terms of curriculum content development, three collaborative lesson-planning sessions have been convened, focusing on textbook contents and teaching key points. Ten discussions on syllabus development have been held, during which several course type recommendations, knowledge point composition suggestions, including basic and advanced sections, and teaching hour recommendations for each knowledge point have been proposed in accordance with institutional orientations. Discussions on the key and challenging teaching points of the database courses involved teachers in the examination of 31 knowledge points. Sixteen experimental and practical training

platform discussions have been conducted, surveying database practical training platforms at both domestic and overseas universities, resulting in a comprehensive resource catalog encompassing nine platforms.

Four types of teaching resources have been developed. The first is course knowledge map. A comprehensive investigation of teaching content of database courses at home and abroad, combined with the characteristics of domestic databases, has been conducted after numerous discussions, resulting in compilation of database course knowledge map. The second is course case library. This is a collective established by the members of TRS create 40 course cases collaboratively, including cultivation of craftsmanship in database practice, initial exploration of ideological and political education in database principles courses, and cases on the development of Chinese database technology. The third is excellent teaching plan library. This is a library contained ten exceptional teaching plans selected from ten universities, such as Shaanxi University of Science and Technology, Beijing Information Science and Technology University, and National University of Defense Technology. The fourth is experimental case library. This library presents ten database experimental cases completed by ten universities, such as Northwestern Polytechnical University and RUC.

In terms of teaching promotion, we have emphasized our teaching philosophies and innovative outcomes on the topic of Moving from Database Usage to Database Creation at prominent seminars, including the Computer Education Conference of China, the National University Computer Professional System Competence Cultivation Summit Forum, "the 101 Plans" Computer Core Course Ecosystem Construction Seminar, and the Future Computer Education Summit. Professor Xiaoyong Du, the leader of our TRS, has been interviewed by Pengyou Moments and China Education Online to discuss the construction and operation of our

TRS.

In addition, we have organized teaching activities for college teachers nationwide, conducted experimental training based on RucBase, and encouraged young teachers, particularly those selected for the MOE's Basic Discipline of the 2.0 Base of Top-notch Students Training Program, to actively participate in database teaching reform practices. We have also hosted two tutorial activities in Longyan, Fujian, in July 2023, and Quanzhou, Fujian, in October 2023.

## 5 Conclusions

The concept of learning from an open-source community has begun to yield tangible results in the VTRS-DB. The VTRS-DB is classified as a symbiotic digital technology-driven open-source community. Therefore, it is essential to reinforce the related principles, accelerate community development through integrated collaborations, and adopt a social value-empowerment operational model. The VTRS-DB has initially established a hierarchical organizational structure comprising committees, working groups, formal members, and observers, aligned with open-source community model. Furthermore, it has implemented a working group operation mechanism for proposal submission, committee discussions, working group implementation, and data uploading of results. Our explorations have been focusing on teaching and research methods from the perspectives of curriculum construction, teaching resources, teaching plan discussions, experimental training, demonstrations, and promotion. The teaching and research room has been selected as a typical VTRS by the VTRS expert group, and the course preparing activity through collaborative teaching has also been chosen as a typical teaching case.

In the face of our emerging model and as a new organization, we have observed both the emergence of numerous excellent and active members over the past year, as well as a significant number of members who rarely participate in activities and make minimal contributions. We aim at drawing inspiration from successful experiences of open-source communities, refine and optimize our operating mechanism and reward and punishment mechanisms within the teaching and research room, and encourage more members to actively participate in activities. We invite members to propose the establishment of new working groups, which will be independently operated under the VTRS framework after approval, and the group leader will automatically become a committee member. To address inactive members, we will implement measures

to discourage non-participation. For example, if a member fails to participate in official activities two times consecutively, he will lose his membership, with the option to reapply. Additionally, we will establish a member honor system. Each working group will quantify participation and contribution based on the above incentives and will use this information as the basis for selecting annual active members. We will also establish a incentive system, conduct annual rewards and honors, and support honorary members in establishing local or national VTRS. Furthermore, we will design a community platform to support the establishment of an honor system, which will not only provide sharing functions for various resources, such as teaching plans, but also provide members with likes and mutual evaluation functions to foster a social reputation and meet external motivations of participating teachers.

In the future, we will continue to focus on four key areas in building our VTRS, including innovating teaching and research models, enhancing pedagogical research, co-constructing high-quality educational resources, and establishing teacher training. These efforts aim at promoting the advancement of database teaching standards in higher education institutions.

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**Data Availability Statements** The author confirms that all data generated or analyzed during this study are included in this published article.

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