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RESEARCH ARTICLE

Joint Construction of Virtual Teaching and Research Section Across Universities: Creating a New Model for Collaborative Teaching and Research

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Abstract The creation and application of massive open online courses, online and offline blended courses, and AI-empowered courses drive the reform in higher education. In this context, the establishment of grassroots teaching organisations should be increasingly promoted. By leading more schools and teachers to more efficiently develop courses and effectively implement teaching reforms through cross-regional and cross-university grassroots teaching organisations, virtual teaching and research section (VTRS) has emerged as a new means to explore the creation of such organisations in the "Internet +" era. This paper introduces the background of the VTRS proposal, analyses the connotations of three types of VTRS, and explains seven characteristics of VTRS. Next, it proposes a VTRS construction framework that involves team building, platform construction, mechanism construction, and content construction. Finally, using computational thinking virtual teaching and research section as an example, this paper introduces the construction cases and methods for VTRS. As a new model of collaborative teaching and research, VTRS will improve teaching skills and research engagements of university teachers and will enhance teaching management and professional development in universities.

Keywords virtual teaching and research section (VTRS), collaborative teaching and research (CTR), massive open online courses (MOOCs), blended courses, online teaching

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1 Introduction

A teaching and research section (TRS) is a grassroots teaching organisation wherein teachers engage in exchanges, discussions, and teaching research, making it a crucial organisation in universities. However, the space–time constraints inherent in a traditional TRS limit cross-institutional interactions and collaborations. The concept of virtual teaching and research section (VTRS) originates from the grassroots educational practices in China and is supported and promoted by the Ministry of Education of the People's Republic of China (MOE) and by the Chinese government. This initiative is grounded in a course-centred and self-organised approach, wherein educators who are part of grassroots teaching organisations collaborate on curriculum development and teaching reforms. In 2021, Department of Higher Education of MOE issued a document entitled *Announcement on Carrying Out Pilot Construction of Virtual Teaching and Research Section* (hereinafter referred to as the "document") (MOE, 2021), marking the beginning of the large-scale creation of Internet-based grassroots teaching organisations in universities. This document mandates the creation of information technology-based VTRS that serves as an avenue for collaborative teaching research. It highlights the importance of VTRS in exploring the construction of new grassroots teaching organisation in the Information Age. In the future, a diverse range of dynamic and open VTRS platforms leveraging the modern information technology will be established. Simultaneously, efforts will be made to create a community conducive for teacher development. On this basis, this paper defines VTRS, describes how it is built and presents how collaborative teaching and research (CTR) is conducted using the VTRS

platform. Thus, this paper serves as a reference for universities that will build and use VTRS.

2 CTR and VTRS in Universities

Since 2013, China has not only created many massive open online courses (MOOCs) but also proposed new models of MOOCs application that combine MOOCs and traditional classroom teaching. These models include small private online courses (SPOCs), MOOCs + SPOCs, and 1 + M + N (Zhan et al. 2015). MOOCs are online courses for unlimited participation and open access. In contrast, SPOCs derive from MOOCs but are tailored for a specific group of students, providing a more controlled and interactive learning experience. The MOOCs + SPOCs model integrates the open nature of MOOCs with the focused approach of SPOCs, combining public access with engagement within a specific group. The 1 + M + N model represents a new collaborative teaching approach, where 1 refers to a group of renowned teachers leading course development, M denotes multiple collaborating universities across regions, and N represents numerous students benefiting from the shared educational resources and teaching expertise. Additionally, the 1 + M + N model integrates MOOCs with classroom teaching, representing a new approach to MOOCs application. Since 2022, AI-empowered courses, or new models of digital and intelligent course construction, have been proposed. These new models provide students with multi-space, multi-channel, and multi-level intelligent learning methods, promoting teaching reforms in traditional classroom, facilitating the sharing of high-quality educational resources and promoting well-balanced education. Furthermore, these courses foster CTR amongst teachers across regions, universities, and disciplines.

2.1 | Current State of CTR in Higher Education

The models and mechanisms of CTR in universities are currently in an exploratory stage. According to Sang et al. (2021), CTR mainly takes one of two forms: One form involves virtual communities, such as QQ groups, WeChat groups, and blog groups; the other involves MIT OpenCourseWare and MOOCs for cross-school CTR. Domestic initiatives, such as education–industry collaborations (Xu et al., 2018), cross-university course development, and university–enterprise course co-construction, have provided valuable insights into the models and mechanisms for CTR. In the new era, as to how to turn the CTR model and mechanism into a norm by using an information technology-based platform has been the focus of universities and educational administrators at all levels.

The existing online collaborative platforms for teachers, such as Edmodo, Moodle, and Google Classroom, provide various tools and environments that allow collaboration and resource sharing amongst educators. Edmodo (Enriquez, 2014) is a social learning platform, enabling teachers to create groups, share resources, assign quizzes, and engage in discussions within a secure, classroom-like environment. Moodle (Gamage et al., 2022), an open-source learning management system, offers a more comprehensive set of tools for course management, collaborative projects, and interactive activities that support both synchronous and asynchronous learning. Google Classroom (Iftakhar & Bangladesh, 2016), integrated with Google's suite of productivity applications, allows teachers to create, distribute, and evaluate in a streamline whilst enabling real-time collaboration and communication amongst students and educators. Whilst these platforms provide valuable support for collaborative teaching and learning, VTRS is a novel model with capabilities that extend beyond the aforementioned typical functionalities. It integrates the benefits of the existing platforms but is specifically tailored to support cross-regional and cross-university collaboration, focusing on collaborative research, co-construction of educational resources, and grassroots-level professional development. Unlike more generalised platforms, VTRS emphasises the creation of a dynamic, decentralised, and teacher-led community that actively shapes teaching and research practices, addressing the limitations of the traditional top–down models.

2.2 | Background of VTRS

Collaborative learning platforms for students, such as MOOCs platforms, have gradually matured, whereas CTR platforms for teachers still warrants exploration. Hence, MOE proposed the creation of VTRS, with a consideration of the following three improvements: MOOC-based teaching reform and creation of national first-class courses, professional reform of "four new disciplines education" and construction of national first-class majors, and concerning new topics in educational reform.

The first enhancement focuses on MOOC-based teaching reform and the creation of national first-class courses. With the evaluation of national first-class online courses and blended courses, the development of high-quality course resources has received active support. This trend not only facilitates the cross-regional and cross-university dissemination and application of quality courses, but also enhances students' learning experiences and promotes the equitable distribution of educational resources. However, the

continuous improvement and the demand for maintenance of such high-quality courses require collective efforts from the teaching community. VTRS provides a collaborative platform for this collaboration, enabling educators from various regions and universities to engage in online discussions, share their teaching experiences, address teaching challenges, and collectively improve teaching quality. Cross-regional and cross-university CTR activities are key to ensuring the quality of first-class courses and maximising the role of MOOCs.

The second improvement is to construct "four new disciplines education" and national first-class majors. The "four new disciplines education" refers to the new engineering, new liberal arts, new agriculture, and new medicine proposed by MOE (2017), with an emphasis on the creation of new disciplines, and new majors through interdisciplinary integration (MOE, 2019). The establishment of national first-class majors requires the continuous introduction and integration of cutting-edge disciplinary knowledge and technologies, which traditional teaching and research models cannot adequately meet. VTRS, through online platforms, break the spatial and temporal limitations of traditional TRS, enabling teachers from different institutions to engage in more convenient interdisciplinary exchanges and collaborations. This CTR is of great significance in promoting the creation of "four new disciplines education" and national first-class majors, which ensures that teachers from different disciplines can fully communicate and collaborate, thereby improving the educational and professional quality. Cross-university and cross-discipline CTR activities for teachers are key to ensuring the quality of the "four new disciplines education" and national first-class majors.

The third aspect concerns new topics in educational reform. The rapidly developing "Internet +" and AI technologies are reshaping the higher education environment. Higher education administrators at various levels have proposed many new topics on teaching reform, such as new colleges, new majors, new training systems, new teaching models, new platforms, new organisations, and new management, especially the recently proposed "AI + higher education". Exploring these new topics requires extensive research and practice by teachers in such areas as teaching methods, curriculum designs, and technology applications. VTRS provides a collaborative platform for teachers across universities and colleges where they can jointly explore and assess the feasibility and effectiveness of new educational reform topics, share practical experiences, and promote educational and teaching reforms. Cross-university and cross-discipline CTR activities for teachers are key to ensuring the feasibility and effectiveness of new topics in teaching reform.

A thorough understanding of the above aspects will lead to a deeper understanding of the value of VTRS and its efficient construction.

3 Essence, Classification, and Characteristics of VTRS

3.1 | Essence of VTRS

This paper revolves around the idea that VTRS is an avenue where a community of teachers from different regions, universities, and disciplines can collaboratively conduct teaching research and discuss reform practices. VTRS, which based on modern information technology platforms in the information society, aims to improve teachers' proficiency and ultimately enhance students' learning.

VTRS shares characteristics with traditional TRS, but there exists differences. VTRS is a new teaching organisation based on the "Internet +", and it is a new form of CTR. Four core connotations of VTRS are as follows: First, VTRS is a grassrooted teaching organisation and teacher community for CTR; second, VTRS relies on an information platform to allow for CTR; third, VTRS is open, accumulative and collaboratively shared—openness means that teachers can dynamically join and leave VTRS platform, accumulation refers to the continuous development and accumulation of achievements, and co-construction and sharing mean that teacher groups can jointly build and share research outputs; fourth, VTRS should establish grassrooted teaching organisations in the future that are cross-regional, cross-university, and cross-disciplinary.

Compared with traditional TRS, VTRS offers several advantages that enhance collaboration, resource sharing, and innovation in teaching methods. VTRS utilizes digital platforms to overcome the limitations of physical space and time, enabling teachers to engage in both synchronous and asynchronous collaborations across regions, which is often challenging in traditional TRS settings. Additionally, VTRS supports blended learning approaches, thus creating more flexible and effective learning environments (Graham, 2013). Furthermore, VTRS provides a decentralized and grassroots-driven model for professional development, empowering teachers to engage in collaborative research and continuous learning, unlike the more hierarchical structures found in TRS. Finally, VTRS enhances the dissemination and application of research outcomes, making it easier for educators to share innovative teaching practices and research findings, thereby broadening the impact of educational research (Pokhrel & Chhetri, 2021). These unique features of VTRS underscore its superiority in addressing the

evolving needs of modern education and in fostering an inclusive and collaborative teaching community.

3.2 | Classifications of VTRS

Based on the background behind the construction of VTRS and its connotations, VTRS can be classified into three types: collaborative construction of VTRS for groups of courses and teachers, collaborative construction of VTRS for groups of majors and teachers, and CTR on new educational reform topics in VTRS.

First, collaborative construction of VTRS is for groups of courses and teachers. This type of VTRS targets teacher groups, providing an avenue for the collaborative development of a single course or a group of courses. It allows teachers to enrich course content and to improve teaching quality through CTR and online exchanges. Figure 1 illustrates the core functions of this type of VTRS. It is essential to note the differences between collaborative learning platforms aiming at student groups and CTR platforms aiming at teacher groups. MOOCs apply the "one teacher to many students" approach to teaching, whereas the MOOCs + SPOCs, 1 + M + N, and similar models apply collaborative approaches. This approach shows "one teacher leading multiple colleges, multiple colleges leading many groups". For instance, a flipped classroom based on MOOCs + SPOCs achieves collaborative teaching between online and in-person classes. AI-empowered courses, such as AI teaching assistants, enable large-scale self-directed learning and personalized tutoring for students, and target of the courses is student. By contrast, the type of VTRS described herein aims to establish a collaborative mechanism amongst teachers to ensure collaborative learning amongst students. Under the guidance of renowned teachers, it should involve a collaborative course design, course case studies, course resource development, and coordination of teaching resource utilization, with a focus on the collaborative development of AI-empowered teaching resources.

Second, collaborative construction of VTRS for groups of majors and teachers. This type of VTRS targets teacher groups, serving as an avenue for the collaborative development of a single specialty or a group of specialties through interdisciplinary and multi-organisation collaboration. For instance, the "four new disciplines education" mentioned above should be jointly developed by teachers from different disciplines, as the innovation potential of the collaboration of teachers specialising in a single discipline might be limited. Meanwhile, the TRS is constrained by the relationships of the participating teachers with their respective administrators, by the lack of dynamicity and openness and by the inability of teachers to effectively solve problems related to interdisciplinary CTR. Therefore, the important function of the VTRS described herein is to facilitate the integration of teachers from different disciplines regardless of their institutional affiliations. It facilitates collaboration on professional training program demonstration, curriculum system design, professional resource development, and teaching reform practices, as illustrated in Figure 2.

Third, CTR on new educational reform topics in VTRS. This VTRS targets teacher groups, serving as an avenue for collaborative implementation of teaching reform practices to establish new paradigms and

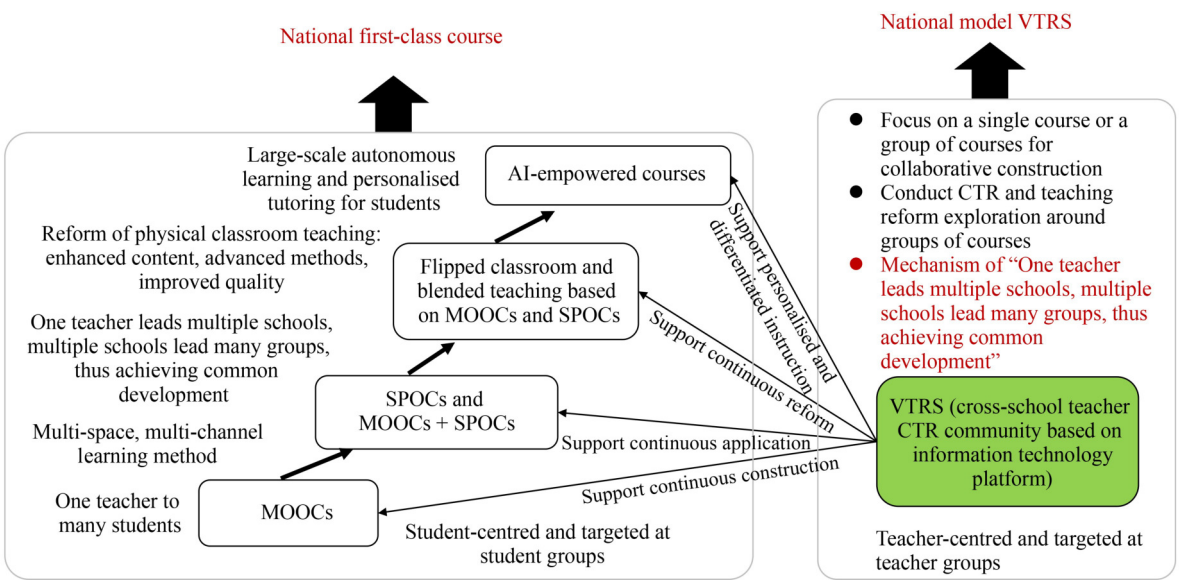

Figure 1 Core functions of the collaborative construction of virtual teaching and research section (VTRS) for courses (groups). AI: artificial intelligence, MOOCs: massive open online courses, SPOCs: small private online courses, CTR: collaborative teaching and research.

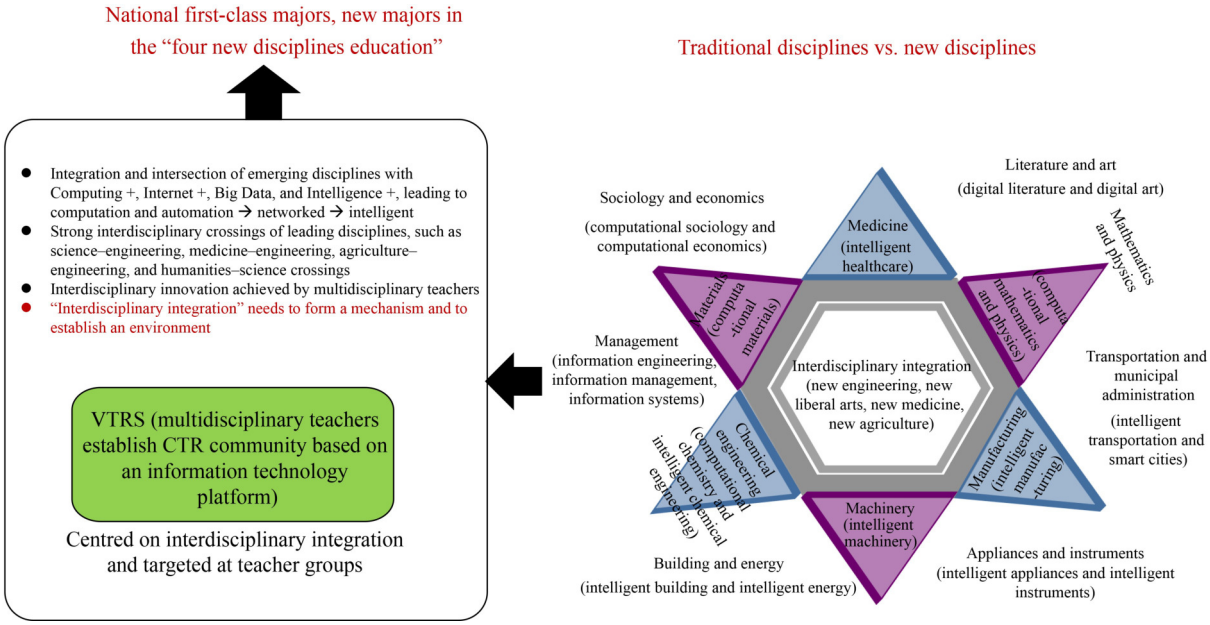

Figure 2 Core functions of collaborative creation of virtual teaching and research section (VTRS) for specialties (groups). CTR: collaborative teaching and research.

achieve outcomes of teaching reform. It supports teachers in jointly exploring and practicing new paradigms through cross-regional, cross-university, and cross-discipline CTR activities. After years of research, experts in the field of computer education have proposed "agile teaching" for the next 10 to 15 years, emphasizing the diversity and evolution of teaching objectives, the flexibility of course systems, the iteration and agility of teaching processes and the synergy of teaching resources. Agile teaching is inspired by agile manufacturing, which was proposed in the United States in the 1990s, and by agile software development in the field of software engineering. Agile teaching aims to rapidly reconstruct teaching systems and processes to address the swiftly changing demands and objectives of talent cultivation. This approach seeks to achieve continuous iteration and optimisation of teaching and talent cultivation, maintaining a leading edge in education. Agile teaching proactively adapts to external changes and challenges, focusing on current and future development of students and fostering talents with sustainable competitiveness.

Future reforms in higher education require changes not only in course systems but also in teaching processes and management, such as implementing complete credit-based and flexible academic systems. Such changes may be difficult to accomplish for a single university or specialty, hence the need for multi-university and multidisciplinary collaboration. The key function of this type of VTRS is to create an environment for multi-regional and multi-university collaborative teaching reform, such as cross-university course selection and credit transfer and recognition; joint establishment of new colleges, platforms, specialties, and models; and exploration of new systems, organisations, methods, and management, especially "AI + higher education". This will form replicable and promotable collaborative teaching reform outcomes, collaboratively advancing teaching reform, as illustrated in Figure 3.

3.3 | Characteristics of VTRS

In the educational context, grassroots organisations refer to groups that operate at the ground level, typically involving frontline teachers and education practitioners who initiate and engage in collective actions. These organisations are practice-oriented, focusing on the real needs of teaching and research and driving innovation and development through the collective power of educators. VTRS exemplifies this grassroots nature by being primarily led by frontline teachers. These teachers utilize their initiative and professional judgment to determine the focus and direction of teaching and research rather than rely on orders coming from a top–down management. This spontaneity and flexibility render VTRS more responsive to the practical challenges and needs of frontline education. From the perspective of construction and operation, this paper revolves around the idea that VTRS has seven main characteristics, including guidance from renowned teachers, focused topic, platform support, pilot demonstration, co-construction and sharing, accumulation of achievements, and improvement in teaching quality.

The first characteristic is guidance from renowned teachers. In ensuring sustainable operation, a VTRS platform must be led by renowned teachers who are movers and shakers. These teachers can organise

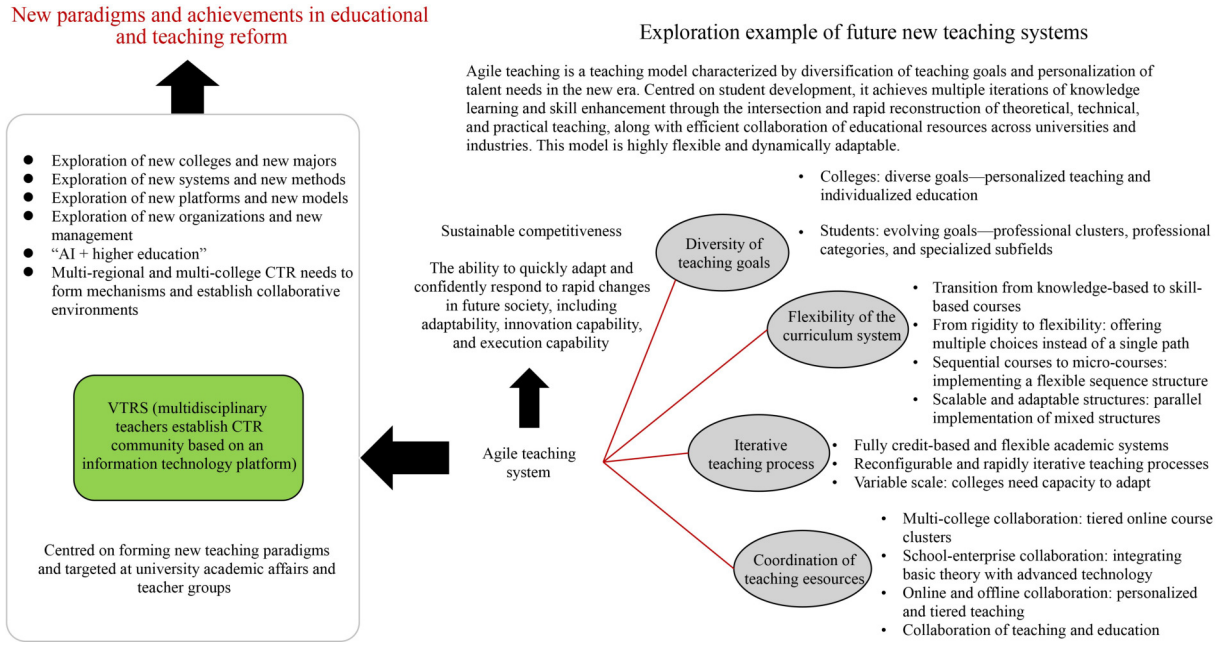

Figure 3 Core functions of collaborative teaching and research (CTR) on new educational reform topics in virtual teaching and research section (VTRS).

key personnel, define research directions, and coordinate teaching research. Candidates for leadership include national and provincial first-class course leaders, first-class professional leaders, academicians, distinguished young scholars, and influential teachers. Such leadership plays a dual role both in setting a benchmark and coordination. In determining whether a teacher can lead a VTRS, it is essential to consider whether he has willingness to open and to help other teachers achieve progress. This leadership structure aligns with the grassroots nature of VTRS, where leadership often emerges organically from within the community of educators. The guidance provided by renowned teachers enhances the credibility and effectiveness of VTRS whilst allowing grassroots-level autonomy and innovation to flourish.

The second characteristic is focused topic. Unlike a physical TRS, a VTRS consists of teachers with common interests and a shared sense of mission. The intrinsic motivation of different teachers to participate in a VTRS is their personal development and the opportunity to showcase their talents. Therefore, the creation of a VTRS requires a consensus amongst teachers in terms of goals and interests in facilitating a CTR. The VTRS must have a clear central focus which is a goal and sustainable tasks that reflect the interests of the majority of its members. For example, if the VTRS is centred on a specific course, the participating teachers must be interested in that course and focus on its development. If centred on a specialty, the teachers must share common professional interests and demonstrate knowledge on certain topics. For a VTRS centred on an educational reform topic, teachers must be interested in this topic and explore it from different perspectives.

The third characteristic is platform support. Public information platforms or intelligent platforms are crucial for the continuous operation and output accumulation in VTRS. They also serve as important tools for cross-regional, cross-university, and cross-disciplinary CTR activities. VTRS built on a public platform needs to establish a virtual research community or a virtual research group in that platform. Teachers can participate in community or group activities and share their research results, and the platform can accumulate and spread these results, maintaining the stability of the VTRS. The flexibility of joining and leaving VTRS, which is allowed by platform, reflects the openness of VTRS. Moreover, the platform's support for VTRS activities embodies the grassroots principle by providing a decentralized space where educators can collaborate and innovate without the constraints of hierarchical structures. This fosters a more dynamic and inclusive environment for teaching and research.

The fourth characteristic is pilot demonstration. VTRS should have pilot demonstration, such as national or provincial first-class courses, and exemplary teaching cases that reflect unique teaching models and resources that teachers may use as references. Model demonstrations can guide teachers and attract them to join VTRS, playing a significant role in their personal development and future research directions.

The fifth characteristic is co-construction and sharing. VTRS is a platform for teacher communities to co-construct and share educational resources.

Participating teachers should actively contribute to resource construction and sharing, supporting the platform's development. A VTRS needs a co-construction and sharing mechanism to protect the rights of resource creators and determine whether resources are open-source or closed-source and whether they are free to use. This co-construction and sharing mechanism is a direct reflection of the grassroots nature of VTRS. It empowers teachers to collaboratively build and share educational resources, fostering a sense of ownership and collective responsibility. This bottom–up approach ensures that educational resources developed align with actual needs of educators and students, enhancing the practical relevance and impact of VTRS.

The sixth characteristic is accumulation of achievements. VTRS is a public information-based platform that allows communities of teachers to gain teaching experiences and promote the application of teaching outputs. VTRS leaders promote the collaborative acquisition of teaching experiences and the expansion of the application scope of teaching results. After joining a VTRS, teachers can adopt other teachers' results and have their own results recognized and applied by more peers through sharing. Teaching research is a continuous process of improving teaching to achieve results, and it can be described as turning "accumulated small results into significant outcomes". CTR in VTRS allows teaching results to be tested in practice and improved based on feedback, promoting their maturity.

The seventh characteristic is improvement in teaching quality. The fundamental purpose of promoting VTRS construction by the state is to enhance teachers' teaching abilities, to strengthen educational and teaching concepts, to improve teaching methods, and to elevate course or specialty construction levels. Many teachers are strongly passionate about teaching but may lack understanding of teaching concepts and may have not received specialised training in teaching methods. In such cases, teachers can leverage VTRS, benefiting from the leadership of renowned teachers and peer exchanges to improve their teaching abilities.

Amongst the seven characteristics of VTRS, the most crucial is co-construction and sharing, the fifth feature. Teachers participating in VTRS must be willing to be open and to co-construct and share. An outstanding teacher is characterised by their willingness to share their experiences and results, such as sharing good ideas and achievements, and their willingness to learn from advanced ideas and results. Through co-construction and sharing, teachers in VTRS can share their teaching resources, such as textbooks, courseware, teaching videos, and exercise banks. This collaborative sharing of resources not only enriches teaching content but also provides diverse learning materials for students, catering to their various learning needs. Additionally, by sharing teaching resources and experiences, teachers can learn from one another, thereby improving their teaching methods and enhancing the quality of their teaching. For instance, an innovative explanation method for a particular concept can be adopted and applied by other teachers, improving their overall teaching effectiveness. The implementation of a co-construction and sharing mechanism eliminates regional and institutional barriers, allowing high-quality educational resources to be adopted and utilized more widely, thus promoting educational equity. For example, universities and colleges with relatively limited educational resources can access high-quality teaching resources through VTRS, leading to an improved educational standards. Moreover, through co-construction and sharing in VTRS, teachers can engage in more teaching discussions and exchanges, broadening their perspectives and enhancing their professional capabilities. This co-construction and sharing mechanism also fosters collaborative innovation amongst teachers, driving teaching reforms. For instance, in developing and implementing of new courses, teachers can collaboratively design course content and co-author textbooks, and conduct joint teaching research through VTRS, leading to the creation of innovative teaching models and methods.

4 Construction Framework of VTRS

4.1 | VTRS Should Encompass Four Key Construction Elements

4.1.1 Team Building

The primary focus of establishing VTRS is team building. This involves organising teachers from different universities and colleges who teach the same course or bringing together teachers from various disciplines to develop new interdisciplinary fields. Team building should be conducted on the VTRS platform, encouraging teachers to join VTRS and ensuring teachers to gain a sense of achievement and belonging. Effective team building goes beyond merely attracting and organising individuals but also involves establishing an organisational structure that ensures efficient operation and sustainable development of VTRS.

Firstly, it is essential to identify distinguished teachers who will be responsible for overall planning and coordination, ensuring that all activities within VTRS proceed smoothly. Additionally, specialised groups should be established, such as course

development group, resource construction group, and teaching research group. Each group should have a leader who will organise and coordinate the work of group members, ensuring that tasks are completed on time. With a well-organised structure and clear division of labour, teachers will understand their responsibilities and tasks, thus encouraging active participate in various activities directed towards a common goal. An effective team-building and organisational structure not only enhance the efficiency of VTRS but also strengthen collaboration and communication amongst teachers. This, in turn, promotes co-construction and sharing of teaching resources, driving continuous improvement in teaching quality.

Secondly, a support team provide technical and administrative support, as well as those responsible for promotional activities. This ensures efficient provision of support in the use of the platform, in daily management, and in the dissemination of outcomes.

4.1.2 Platform Construction

The VTRS platform should primarily carry out the following functions: First, support the initiation of and promote participation in CTR activities and sharing of relevant materials, amongst others. CTR includes the collaborative conduct of teaching research projects, design of lesson plans, compilation of textbooks, creation of teaching video resources, and development of question banks and related topics; second, facilitate CTR activities through video and voice conferencing; third, enable sharing, dissemination, and application of teaching outcomes; fourth, publish and showcase the activities and results of the VTRS; fifth, offer various training sessions on VTRS, such as live video broadcasts and teaching case presentations. The two basic requirements for a virtual teaching and research office are a good team and team members who carry out collaborative teaching and research work on the platform.

For instance, for the course, introduction to computational thinking, universities and teachers may engage in CTR activities, joint instructional design, discussion of teaching cases and teaching conferences by using the VTRS platform. Information related to these teaching and research activities, such as images and videos of various teaching events, videos of special lectures and recordings of teaching seminars, may be shared in the VTRS. Collaborative instructional design efforts may include the joint creation of course knowledge graph (KG), teaching manuals, and teaching case libraries. An example is the teaching design based on the KT-SQEP, which stands for knowledge, thinking and sequence, example, question, and practice, and includes the development of KG and teaching manuals. Additionally, collaborative efforts can lead to the creation of teaching cases, which consists of teaching content, instructional design, implementation, and reflection, as well as demonstrations of teaching, courseware, and lesson explanations.

4.1.3 Mechanism Construction

A VTRS needs an effective operational system. Although composed of teachers from various disciplines and from different universities, VTRS does not need to alter administrative management relationships of its participants. Instead, it requires a regular operational mechanism to ensure sustainability of VTRS. This mechanism includes a well-organised structure and operational rules of VTRS, and the core operational system involves co-construction and sharing mechanism, such as mechanisms for publishing and using achievement, and CTR mechanism for participating teachers, such as mechanisms for issuance, response, submission, and administration of collaborative tasks. Participants in VTRS are encouraged to maintain an open attitude and preferably provide their resources for free. Concurrently, VTRS should establish systems that would encourage more teachers to open their resources and protect their legal rights.

4.1.4 Content Construction

In building VTRS platform, content sections must be set up to support CTR activities of VTRS and the continuous accumulation and sharing of relevant results. Generally, VTRS may comprise six content sections, including course design and exchange section, collaborative teaching research project section, co-construction and sharing of teaching resources section, collaborative teaching reform practice activities section, teaching achievement accumulation section, and specialised lectures and teacher training section.

The first content section is the course design and exchange section. This platform is aimed at a collaborative construction of groups of courses and participants, teachers can use this section to publish course outlines, syllabus, lecture notes, typical exercises, and topics in standardised document formats for exchange. In a cross-university VTRS, different universities can use this section to publish their course outlines and teaching documents for discussion and mutual learning. When consensus is reached on related teaching issues, standardised teaching documents can be created to provide guidance on course reform to the teaching committees of each university. However, it is not mandatory for universities to follow these documents in VTRS; rather, documents serve as references to support universities to improve their curricula whilst maintaining their unique identity and autonomy.

The second section is collaborative teaching

research project section. This section includes suggestions for project proposals, for the refinement of joint application forms, for tracking research progress, for publication of mid-term summaries and final reports, and for accumulation of project outcomes.

The third section is co-construction and sharing of teaching resources section. Teaching resources include textbooks, lecture notes, teaching cases, teaching videos, question banks, and topics. Through this section, VTRS serves as avenue where teachers can collaboratively build, apply, and promote teaching resources, thus leading to resource co-construction and sharing.

The fourth section is collaborative teaching reform practice activities section. Using this section, teachers from different universities may collaborate to conduct teaching reform practice, such as joint teaching activities of the same course across universities, cross-university teaching demonstrations by renowned teachers and joint teaching seminars. This maximises the co-construction and sharing of quality resources, promoting educational equity.

The fifth section is teaching achievement accumulation section. Small teaching outputs may accumulate, expanding from a single point and are continually refined and improved. For example, when compiling textbooks, teachers prepare and refine materials chapter by chapter. Before the textbook is completed, teachers may accumulate their teaching outputs and continually improve them in this section. Different universities may reference and select materials when organising textbooks that suit their preferences. Additionally, the VTRS platform should provide functions for disseminating outputs, facilitating the application, and promoting the accumulated outputs.

The sixth section is specialised lectures and teacher training section. Teachers can use this section to publish specialised training videos, organise live video training sessions, and receive synchronised remote teacher training.

In summary, VTRS construction focuses on collaboration on course development, projects, resource construction, and teaching activities, as well as on accumulation, co-construction, and sharing of outputs. Moreover, it should support various forms of exchange activities, such as document exchanges, live audio and video meetings, and instant messaging exchanges.

5 Construction Cases and Methods of VTRS

To briefly introduce the construction and operation of VTRS, this paper uses as example the computational thinking virtual teaching and research section (CT-VTRS) established on higher education VTRS platform.

5.1 | Introduction to CT-VTRS

The CT-VTRS is based on the work of the college computer course teaching team, established in 1998 at the Harbin Institute of Technology, which taught the first computer course at the university. It originated from the output of College Computer Course Working Group, established in 2015 at the Computer MOOC Alliance for Higher Education, and the Cross-University Teacher Team for College Computer Courses, established in 2016 at the National Higher Education Teaching Research Center, China. It now involves 498 teachers from over 220 universities across the country.

5.2 | Construction Case of CT-VTRS

The CT-VTRS has gathered numerous renowned national and provincial teachers, first-class course leaders and awardees of national and provincial teaching innovation competitions and thus is characterised by "renowned teacher leadership" model. At its inception, the CT-VTRS established the following consensus: the comprehensive teaching of computational thinking in college computer courses; combining MOOCs and blended teaching to ensure high-level, specialised, and differentiated outcomes, thereby improving the quality of computational thinking education; and adhering to an open attitude and practicing the "I help everyone, everyone helps me" philosophy so that every participant can achieve excellent teaching results. The objectives of the CT-VTRS are delineated as follows: to pool efforts to enhance course content; to co-construct and share resources, thus enriching course resources; to inspire teaching methods through collective insights; to help individuals to achieve synchronous improvement; and to work together to create teaching achievements. The CT-VTRS emphasises supporting members in improving ideas, content, methods, textbooks, and resources. It encourages them to participate in teaching innovation competitions, to apply for first-class courses, and to aim for teaching achievement awards. This reflects the characteristic of "focused topic" and reinforces a "co-construction and sharing" philosophy in developing computational thinking courses and blended teaching reforms.

The CT-VTRS is established on a public information platform, known as the Higher Education VTRS Platform. It includes various sections, such as universities, teaching resources, research achievements, research materials, computational thinking program practice in CTR section, and 20 lectures on computational thinking, wherein course outlines, teaching requirements and other documents were

gathered from relevant universities. It also includes course training videos for teachers, lecture notes, question banks, and teaching resources, as well as special lecture videos on teaching innovation, first-class course construction, teaching achievement awards, and related course teaching cases, such as PPT cases, lecture videos, and classroom teaching videos. Additional sections, such as course discussions, teaching meetings, course ideology and politics, question bank construction, student feedback, and teaching activities' greatly enrich the types of activities and the accumulation of results in TRS. This reflects the characteristics of pilot demonstration and accumulation of achievements. These gathered teaching results are important factors that attract teachers from various universities to participate.

With the use of the CT-VTRS platform, two textbooks for the core curriculum which is the introduction to computer science core course, are collaboratively completed: One textbook is entitled *Introduction to Computer Science—Computing +, Internet +, and Artificial Intelligence +* and the other is entitled *Introduction to Computer Science—Computational Thinking Program Practice*. About 40 teachers from 12 universities collaboratively develop theoretical courses, including KGs which consist of 7 modules, 18 knowledge units, 45 knowledge points, 86 teaching manuals, 16 CourseWares, 1 textbook, over 140 real-person teaching videos, 40 digital-person teaching videos, and 20 virtual classroom teaching scenarios. On the EduCoder platform, 6 universities collaboratively develop practical courses, including 14 practical projects, 14 KGs, 232 programming tasks, over 650 functions, 1 practical textbook, 14 initial version project simulation programs, and over 70 online practice guidance environments for 14 practical projects. According to the summary data of the VTRS platform, CT-VTRS has gathered 984 teaching resources which ranks 9th on the platform, 73 research outputs, and 84 research materials and has organised 153 research activities which ranks 43rd on the platform. Two cross-university collaborative teaching reform practice cases, such as K + M + N cross-university collaborative practice case and clone class cross-university collaborative teaching case, are included as amongst the 16 typical cases in the *Road to Equity: Report on the Development of MOOCs in the West*. These cases are demonstrated and exchanged at the MOE's MOOCs to the West Conference in Yan'an. In the 2024 typical case review for VTRS, it has won the titles "Typical VTRS", "Typical Research Methods", and "Typical Research Achievements." The impact of these implementations is evident through the progressive development of the first university-level computer course, which evolved from software usage and basic computer concepts to computational thinking and its integration with AI. Additionally, CT-VTRS has hosted 23 online seminars and 24 offline training sessions, effectively enhancing teachers' skills and promoting innovative teaching practices across institutions.

5.3 | Construction Methods of CT-VTRS

The CT-VTRS has proposed three methods for core course co-construction and three models for cross-university collaborative teaching research. Some typical models and examples are shown in Figure 4. These three methods include teaching design method based on the KT-SQEP knowledge graph, practical course construction method of self-evolution, stepping, empowering, and innovation (SSEI), and resource construction method from a real-person video to a digital human–virtual scene interactive.

The first method is teaching design method based on the KT-SQEP knowledge graph. This method combines content and teaching techniques in the form of a graph, helping teachers refine course content and improve teaching methods. It developed a KT-SQEP KG modelling tool to support teachers when conducting teaching design using KGs. Based on the levels of knowledge, thinking and essence, a new teaching method that incorporates teaching content and sequence, interactive questions, practical examples and exercises is proposed, and it is referred to as KT-SQEP. This method organically integrates the construction of KG, teaching content and teaching methods to create an innovative teaching approach. Teachers can set different teaching objectives and scenarios, drawing a KG that deepens a teaching content and optimises teaching methods. As a result, the course KG enhances the depth of the educational material and improves instructional techniques; thus the educational goals are achieved.

The second method is the practical course construction method of SSEI. This method divides practical projects into a five-level progressive programming task model and a one-level non-programming task model, enabling students to write, apply, and iteratively evolve computing and simulation programs within a unified framework. Through this approach, students can progressively master complex programming skills by completing simple tasks, ultimately achieving a unified framework for independent writing, applying, and iteratively improving simulation programs. The SSEI method not only focuses on cultivating students' programming abilities but also enhancing their innovation capabilities. It encourages students to engage in self-directed learning and exploration whilst solving real-world problems, thus strengthening their innovative thinking and practical skills.

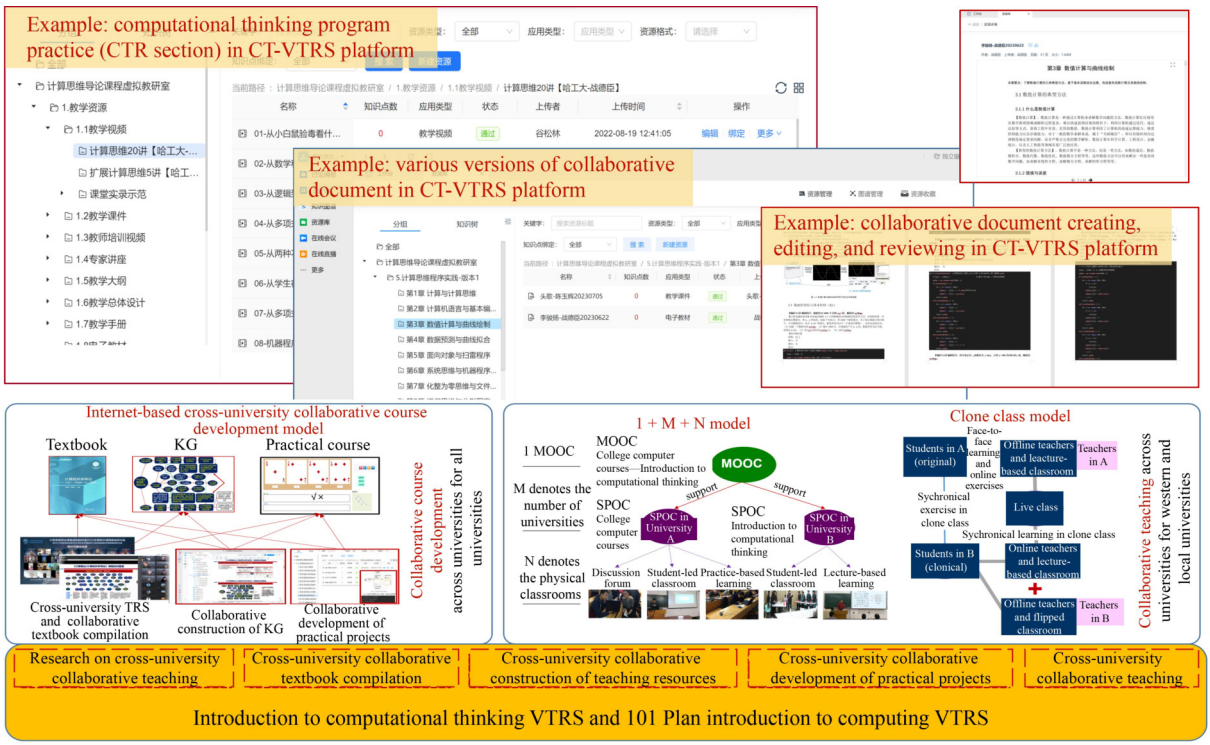

Figure 4 Some typical models and examples implemented by computational thinking virtual teaching and research section (CT-VTRS). CTR: collaborative teaching and research, VTRS: virtual teaching and research section, TRS: teaching and research section, KG: knowledge graph, MOOC: massive open online course, SPOC: small private online course.

The third method is resource construction method from a real-person video to a digital human–virtual scene interactive. Based on real-person teaching videos, this method uses AI technology to extract educational content to create distinctive digital human teaching videos. It further improves digital human–real person interactive digital classroom, laying the foundation for metaverse teaching, which is based on virtual reality.

There are three models for cross-university collaborative teaching research, including Internet-based cross-university CTR model, clone class cross-university collaborative teaching model, and K + M + N cross-university collaborative practical course co-construction and sharing model.

The first model is Internet-based cross-university CTR model. This model involves conducting cross-university exchanges and discussions through video conferencing, collaborative editing of cross-university textbooks through document collaboration, building of cross-university practical projects through resource collaboration, and gathering cross-university resource construction results in resource libraries.

The second model is clone class cross-university collaborative teaching model. This model involves multiple universities that simultaneously offer the same course, leveraging digital technology for cross-university teaching and practice. In addition, the 1 + M + N cross-university teaching model is practiced.

The third model is K + M + N cross-university collaborative practical course co-construction and sharing model. In this model, K universities collaboratively develop practical projects to co-construct courses, M universities collaboratively offer practical courses based on a developed project to co-offer courses, and numerous students (N) complete online practicals remotely. It is a large-scale experimental course construction and application model.

In the future, the CT-VTRS will build upon the aforementioned work, organising teaching activities through such sections as collaborative projects, collaborative textbooks, and collaborative teaching material library, and using various formats, such as live broadcasts and “online + offline” methods to share activity results in the form of images, videos, and documents. The goals are to gather renowned teachers, target nationwide, lead course transformation and upgrading, promote co-construction and sharing of resources, and lead flipped classroom practice, transforming the VTRS into a platform for cross-university course collaboration and exchange, demonstration and promotion of a new model, course resource construction and sharing, accumulation and display of results achieved from cross-university collaboration and for training of teachers on the use of new teaching models, ultimately achieving the catchphrase “One teacher leads multiple universities, multiple universities lead many groups, thus achieving common development.”

6 Conclusions

This paper presents three primary motivations for proposing VTRS; elucidates its connotations, classifications, and characteristics; constructs a framework for building VTRS; and introduces construction cases and methods. As an innovative form of grassroots teaching organisation, VTRS offers significant advantages. Firstly, it transcends the temporal and spatial limitations of traditional TRS, allowing educators to engage in cross-regional, cross-university, and cross-disciplinary teaching collaborations. This flexibility not only promotes sharing of high-quality educational resources but also promotes the professional development of teachers and improves their teaching quality. Secondly, it fosters openness and sharing of teaching resources through a co-construction and sharing mechanism, stimulating teachers' creativity and enthusiasm, thereby providing robust support for educational reform.

However, the implementation of VTRS is fraught with challenges. Teachers' awareness and acceptance of VTRS vary, and some teachers face difficulties in mastering and applying new technologies. Additionally, the continuous operation and maintenance of VTRS require stable technical support and management mechanisms, which may not be fully established in some institutions. To address these issues, it is necessary to enhance training and publicity. By organising training sessions, seminars, and promotional activities, teachers' awareness and acceptance of VTRS can be improved. Moreover, equipping them with necessary skills and methods needed to use the platform effectively may boosting their enthusiasm for participation. Establishing comprehensive support and management mechanisms is also crucial. Providing stable technical support for VTRS, setting up professional technical teams responsible for platform maintenance and troubleshooting and developing clear management policies and operational procedures can ensure the standardised and sustainable operation of VTRS.

Encouraging and motivating teacher participation is another critical consideration. Giving of awards that acknowledge one's contributions to VTRS, recognising excellent resources and research outcomes, and incentivising teachers to actively engage in co-construction and sharing activities are effective strategies. Furthermore, policy support and financial investment can provide teachers with the necessary resources and conditions, driving the development of VTRS. As this pilot work on VTRS progresses, universities and educators will further explore this platform. Much like MOOCs that have revolutionised classrooms and learning, VTRS will foster CTR amongst educators, enhance the quality of course development, promote interdisciplinary integration and facilitate the development of new teaching paradigms and mechanisms. The widespread application of VTRS is poised to bring new opportunities for the advancement of higher education, offering a broader platform for teachers' professional growth and students' comprehensive development.

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Conflict of Interest The authors declare that they have no conflict of interest related to the content of this paper.

Data Availability Statements The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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