

Exploring Potential of Project-based Learning in Enhancing Operation and Management of Urban Rail Transit Teaching in New Era of Artificial Intelligence

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Abstract

Given the interdisciplinary nature of the transportation field, the operation and management of urban rail transit (OM-URT) involves a various area of scopes. With the advent of the fourth industrial revolution age and new generation of information technique, as well as the generative Artificial Intelligence, the pedagogy has gone through a series of changes, such as the emergence of the project-based learning. The purpose of this study was to expose the project-based learning on the development of OM-URT course, with regards to three core objectives, i.e., critical thinking, higher order thinking, and complex problems-solving skills. Firstly, we present an overview of the OM-URT curriculum, schedule, and objectives. Secondly, three projects are described that covers a range of topics about OM-URT, including the learning prerequisites, the tutorial for OM-URT with the project-based learning, and project library. Thirdly, the outcome assessment of the OM-URT curriculum are summarized, including the students' anonymous questionnaire feedback. The project-based learning method could not only equip the students with academic achievements on the course OM-URT, but also facilitate seamless cooperation and collaboration among the students under the guidance of the teachers during the development and modification of the solutions and schemes for the OM-URT projects. It is instrumental in practicing and training complex skills in higher education, e.g., OM-URT course.

Keywords

Operation and Management of Urban Rail Transit (OM-URT); Project-based Learning; Critical Thinking; Higher Order Thinking; Complex Problem-solving Skills; Artificial Intelligence.

1. Introduction

The art of teaching, Mark Van Doren said, is the art of assisting discovery. As a tutor in charge of the transportation subject, one of the main tasks is to assist students in discovering transportation industry to contribute for the new quality productive forces, including the urban rail transit system. Though the previous exam results can be used as good predictors for next exam results, they can't forecast the students' performance in the project-based task with the positively correlated expectations [1], particularly in the new era of Artificial Intelligence (AI). Education is not just about acquiring knowledge. Education is a complex process in which we not only acquire knowledge of various concepts but also learn to apply them in daily life with our social skills, e.g., developing solutions and solving problems in a comprehensive and cooperative manner with STEAM (Science, Technology,

Engineering, Arts, and Mathematics) [2]. The tutors/instructors should define the teaching strategies according to the context of the specific course.

According to the student standards from ISTE (International Society for Technology in Education) issued in 2016, the students should be fostered as an enabling learner, an innovative designer, a computational thinker, a digital citizen, a knowledge builder, a creative communicator, and a global collaborator in the new era of AI, so as to support the learning capability for the students' future career, in terms of critical thinking, problem-solving skills, communication and collaboration skills, creativity, self-recognition and management, and emotion intelligence (how to face the failures), etc. Project-based learning (also called problem-based learning) is a kind of dynamic pedagogy centered on students by-group basis. The other key features of project-based learning activities involve the projects/problems-orientation, targeting at training the students' self-directed and self-regulated learning ability.

With the advent of the fourth industrial revolution age and new generation of information technique, as well as the generative Artificial Intelligence, the pedagogy has gone through a series of changes, such as the emergence of the project-based learning. Meanwhile, the application of artificial intelligence (like machine learning, and reinforcement learning) and artificial generative intelligence (like ChatGPT, and GPT-4) in the traffic planning and management for rail transport [3,4] has enriched the contents and forms of the project-based learning method, and also given the students the access to a comparison study between what exists in practice and what reveals by experimental theory, i.e., the gap between theory and practice. An interdisciplinary approach is required to integrate several fields for project-based learning and tutoring on the Operation and Management of Urban Rail Transit (OM-URT) course. In education, AI supports and enhances learning environments by employing intelligent tutoring systems, intelligent agents, and intelligent collaborative learning systems.

Various educational technology platforms have adopted the function of Artificial Intelligence, e.g., Virtual Mentor [5], Voice Assistant, Smart Content, Presentation Translator, Global Courses, Automatic Assessment, Personalized Learning, Educational Games, and Intelligent Tutoring System (ITS). In order to predict student engagement, certain machine learning algorithms can be applied to analyze student learning behavior [6]. Aiming at estimating success in project-based learning, SPIKOL, Daniel, et al. [7] leveraged face and hand tracking in workshops with engineering students, which concluded that results generated from multimodal data can be leveraged to inform instructors/teachers about key characteristics of project-based learning activity, such as student academic motivation [8].

The Intelligent tutoring systems [9] or intelligent assistants [10] designed with AI techniques can be integrated with the student model, the teacher model, the domain model, and the diagnosis model [4]. For the student model, it can offer the information about the students' cognitive ability, knowledge level, learning motivation, and learning styles. For the teacher model, it can provide assistance and guidance, select teaching strategies and methods, and analyze the current state of students. For the domain model, it can represent the knowledge towards both teachers and students. The diagnosis model can assess the errors and defects based on the domain model, and help teachers define their teaching strategies, according to the context of a specific projects.

By fostering collaborations, problem-solving skills, higher order thinking skills, and curiosity, project-based learning empowers students majoring transportation to thrive in a global environment increasingly shaped by scientific and technological advancement [11,12]. Within the immersive project-based learning environment, students can engage in more interactive and dynamic learning experiences, inspiring their critical thinking, individual and collective wisdom and intelligence, their imagination, and enforcing their short-term and long-term memory and comprehension. Additionally, the project-based learning illustrates the promise in enhancing students' complex problem-solving skills, boosting academic outcomes, learning performance, and a better understanding of the course and subjects, by creating a brandnew learning style that facilitates high engagement through

immersive study experiences. The actual gap on the stated topic/problem about the project-based learning is that few of them covers the topics about the course OM-URT.

This study proposes the integration of project-based learning into the course Operation and Management of Urban Rail Transit (OM-URT). The primary focus is on building several projects surrounding operation and management of urban rail transit (OM-URT), providing students with a blended learning [13] space to design and propose OM-URT related solutions and schemes for improving the processes of transportation industry. The final goal is to help students familiar with the practice and application of emerging technology in their degree course and subjects and future professional endeavors, empowering them to present their solutions and schemes in a more natural and professional manner. By creating a dynamic and engaging environment during research for the projects, the proposed work methodology not only provides valuable learning opportunities, improving students' technical skills while promoting efficient project collaboration and management, but also cultivate an organized and collaborative approach/manner to project development, facilitating them to grasp the skills indispensable for professional success.

The process of learning is as knowledge construction, creation, and building. Centering on the complex problem-solving skills, there are two other main study instruments for OM-URT in the new era of artificial intelligence, i.e., the critical thinking, and the higher order thinking skills. In the teamwork for the project, the positive interaction among the students are encouraged via exchanging arguments, asking questions, sharing knowledge, and formulating new ideas. As one of the elementary goals of the education systems, to a certain extent, the critical thinking is equivalent to the processes of scientific thinking [14], which involves problem recognition and definition, collecting effective information for a better understanding of the issue, evaluating various scenarios associated with the issue, providing and assessing the feasibility of the solutions, and logical decision-making. In these senses, the critical thinking requires the active engagement of the students during the educational process. Both knowledge comprehension and its application to new contexts are the features of higher order thinking skills. With these regards, the higher order thinking skills are equipped with the capability to not only apply knowledge in complex problem solving, but also create something new, which measures the Bloom's Taxonomy's three highest levels [15], i.e., analyze, evaluate, and create.

The rest of this study is organized as follows. Section 2 presents an overview of the OM-URT curriculum, schedule, and objectives. Section 3 describes three projects in details that covers a range of topics about OM-URT, including the learning prerequisites, the tutorial for OM-URT with the project-based learning, and project library. Section 4 summarizes the outcome assessment of the curriculum, including the students' anonymous questionnaire feedback. Finally, Section 5 concludes this study with key recommendations.

2. Curriculum

The field of urban rail transit originates from railway and urban transport, but it is strongly affected by other disciplines such as civil engineering, transportation, economics, mechanics, operational research, urban planning, computer science and engineering, service science, and management science, etc. Given the interdisciplinary nature of the field, the operation and management of urban rail transit (OM-URT) involves a various area of scopes. For the purpose of the analysis of OM-URT in higher education, it is desirable to clarify the related terminology firstly. With the advent of Internet and World Wide Web in 1990s, the online or blended learning, e.g., Massive Open Online Courses-MOOCs, can provide a large volume of resources for various subject and course/curricular study [16], including the OM-URT course and its associated transportation subject.

The educational level suitable for OM-URT curriculum usually refers to the sophomore, junior, or senior undergraduates. At the micro-level, several factors would impact the learning curve or effectiveness towards the project-based learning for the OM-URT curriculum, from the perspective of the students, they include (but not limited to) the motivation, learning style, and

information/literature retrieval skills, etc. From the perspective of the professors, they include (but not limited to) the guidance role, teaching mode (managerial, cognitive, affective), professional skill, and the level of information technology skill, etc. One of the key responsibilities for the teachers during tutoring the project-based learning is to take the student concerns seriously, especially those valid concerns, such as mastering emerging technology and software, comprehending new curricular concepts and terminologies, and striking a desired balance between traditional education and e-education, etc. From the perspective of technology, they include the platform used, the perceived convenience for teamwork [17] collaboration, and the perceived ease of understanding the associated projects.

The current era for academic and pedagogy characterized by an excessive use of information technology and a permanent interconnect between different disciplines has also pushed the OM-URT curriculum to be shifted from tradition teaching pattern to the more suitable project-based learning mode, so as to equip the students with the adoption of multitudes of methods such as optimization, simulation[18], digitalization and digital twin, big data analytics, and artificial intelligence. Particularly, both simulation (e.g., simulation for what-if analysis) [19] and optimization (e.g., optimization of train operation plans), as well as the integration of these two techniques into Decision Support Systems (DSS) are indispensable mechanisms for facilitating the modeling of real problems and adding value to transportation related OM-URT projects, so as to visualize the possible effects of future scenarios and offer the decision chain with high flexibility and feasibility.

Bloom's taxonomy of education objectives is a hierarchical structure that classifies cognitive levels involved in learning, ranging from basic to advanced levels. By engaging students across multiple levels of cognition through projects, project-based learning can promote deeper understanding and mastery of complex terminologies and skills. Our OM-URT course has three high-level learning objectives:

Objective 1 of OM-URT: Design of train operation plan and critical thinking via learning by doing. According to the features of the research objects in the transportation field, based on the survey of passenger flow and analysis of operating costs, design the train service and operation plan of OM-URT by using the principles, techniques and methods of management science, service science, and system optimization, from the perspective of passenger demand, capacity supply, and reducing cost to increase benefit.

Objective 2 of OM-URT: Evaluation and higher order thinking via learning by doing. Analyze and evaluate the impacts of various train service plan and associated index of the practical urban rail transit problems on the human society, the economic profits of the operating firms, the environments, and the sustainability development, by using the associated knowledge of transportation subject and the main ingredients of OM-URT, artificial intelligence (AI) [3] and big data analytics [20].

Objective 3 of OM-URT: Intelligent decision-making and complex problem-solving skills via learning by doing. Effectively and scientifically plan, organize, schedule, coordinate, control, and evaluate during the planning and implementation of multidisciplinary projects in the complicated and networked operation scenarios, by comprehensively using the transport-operational research, AI-based intelligent decision-making, and system optimization and simulation, so as to improve the service and management quality of urban rail transit, and lower the operating costs and risks.

Our course OM-URT spans eight weeks. The course schedule from our most recent offering is shown in Table 1. The projects will be described in details in the next section.

Table 1. course schedule of OM-URT

Weeks	Topics	Objectives	Projects
1-3	Planning technique for metro train operating, theory and computation of metro transport capacity, timetabling and scheduling technique, metro train operation control technique, technique for metro station management and organization of passenger flow.	Objective 1	Metro train timetabling
4-5	Fundamental concepts of train operation and passenger travel, feature of metro transportation organization, analysis of passenger flow characteristics and principle of service design, theory and method of ticket revenue management.	Objective 2	Metro ticket revenue clearing
6-8	Organization technique for networked metro operation, technique for metro capacity reinforcement and operating speed upgrade, organization method for daily normal passengers and large volume of passenger flows.	Objective 3	Pre-plan compiling for metro passenger flow control

3. Projects

Knowledge application in the associated situations/projects has ever been highlighted for the development of complex engineering and academic skills [21], i.e., complex problem-solving capability. One of the goals of the project-based learning is to create a learning environment and scenario to practice and facilitate the acquisition of target complex skills, by handling various authentic problems. And the other cognitive-processing goals include critical thinking, higher order thinking, communication, monitoring, and collaboration, etc. It has been recognized that learners with different levels of prior knowledge would benefit from different types of projects [22].

3.1 Learning Prerequisites

Learning and comprehending transportation related concepts lay the foundation for the OM-URT with project-based learning. OM-URT learning can be impressive and effective to get started with concepts and terminologies in planning and management of transportation, operation and management of urban rail transit, planning and design of urban rail transit, computer engineering, information and communication technology. Integrating AI into curricula is necessary to train citizens who must increasingly live and act in a world with a significant presence of AI. Besides the domain-specific knowledge, the skills in mathematics, operational research, computer science and programming, and other related unstructured knowledge are indispensable.

In order to lay a solid foundation for the OM-URT related projects development, a package of easy use is necessary to be practiced, which involve the easy-to-learn programming languages (e.g., Python, and Julia), easy-to-learn modelling and optimization tool/software(e.g., Open Solver for Excel, Cplex, Gurobi, and LINGO) , easy-to-learn statistical and data analysis environments (e.g., SPSS, Minitab, Tableau, and SAS), easy-to-learn math environments (Matlab, Maple, Mathematics, and Mathcada), the promotion of the use of online collaborative tools (e.g., Overleaf for Latex, and Google Docs for word processing files), and the promotion of teamwork for complex problem solving. Moreover, the associated transportation professional simulation/optimization software, e.g., Railsys, or OpenTrack, is a necessity.

When students encounter difficulties, the instructor/tutor/teacher will guide them by providing prompts, cues, and suggestions, which could help the students enforce their existing knowledge and link new ideas with those they already grasped. In this manner, instructors/teachers could tailor their assistance to the specific needs of each team of the projects.

3.2 Tutorial for OM-URT with the Project-based Learning

To keep the students with different levels of prior knowledge informed and inspired, we develop and issue the Tutorial for OM-URT with the project-based learning as Tutorial 1.

Tutorial 1: Tutorial for the project-based learning with OM-URT course

Step 1: deliver OM-URT domain-specific knowledge and skills.

Step 2: design and issue project library for OM-URT.

Step 3: set N = number of projects in the project library, set $m = 0$.

Step 4: specify a project.

Step 5: set $m = m + 1$.

Step 6: teachers define their teaching strategies.

Step 6.1: learners with high prior knowledge benefit from reflection phase.

Step 6.2: learners with low prior knowledge are supported by examples.

Step 7: problem description and definition for the project.

Step 8: recognized the difference between well- and ill-structured problems.

Step 9: generating hypotheses and modelling.

Step 10: algorithm/solution development.

Step 11: data access and collecting case-specific information.

Step 12: simulating/optimizing/coding with case study or numerical study.

Step 13: results and data visualization.

Step 14: comparison study between what exist in practice and what reveal by experimental theory.

Step 15: discussion on the results on future research agenda.

Step 16: restructuring OM-URT domain-specific knowledge/skills into higher order concepts and drawing conclusions.

Step 17: report findings in a written document for the project.

Step 18: prepare a 5–10 min PowerPoint presentation that poses the question, summarizes the findings, and offers a conclusion for the project.

Step 19: if $m < N$, turn to Step 4; else turn to Step 20.

Step 20: summarize the entire OM-URT curriculum in terms of critical thinking, complex problem-solving skills, higher-order thinking skills, logical decision-making, and assess the students' own performance, as well as plan further improvements, etc.

3.3 Project Library

Besides introducing the AI elements and other emerging technologies in OM-URT course, project-based learning offers learning with concrete tasks and problems on the basis of the student study-cycle, i.e., project library, which facilitates learning from practicing to develop complex skills.

3.3.1 Metro Train Timetabling

Train timetabling is one of the challenging combinatorial optimization problems in the railway system with great significance. There are two versions of train timetabling problem, i.e., the cyclic version [23], and the non-cyclic version [24]. For this metro train timetabling project in our OM-URT course, the Qingdao Metro Line 13 of China was taken as a real-world study object, and the undergraduate students are required to answer the following fundamental problems:

- Self-directed and self-regulated to be an enabling learner and an innovative designer.
- The factors, elements, and assessment index of the timetable?
- The required resources and the compiling steps for daily metro train operation plan?
- The requirements, the compiling steps, and the resources needed to collect for the metro train timetabling?
- The do's and don'ts for metro train timetabling?
- The main principles for the adjustment of the metro train timetable?
- Analyze the adaptability of the cyclic timetable and non-cyclic timetable.
- Survey the theory and method for train operation plan and timetabling.
- Analyze the objectives, constraints, models, and solution algorithms for metro train timetabling problem.

- Search for the associated resources, combine with the field survey, and compile the daily train operation plan for Qingdao metro line 13 by using the suitable technique.
- Search for the associated resources, combine with the field survey, compile the train timetable for Qingdao metro line 13 by using the suitable technique.

This project can help students get a better understanding of the full processes of the train operation planning and timetabling technique via learning by doing, some examples of the implementations about the project are demonstrated as Figure 1 and Figure 2.

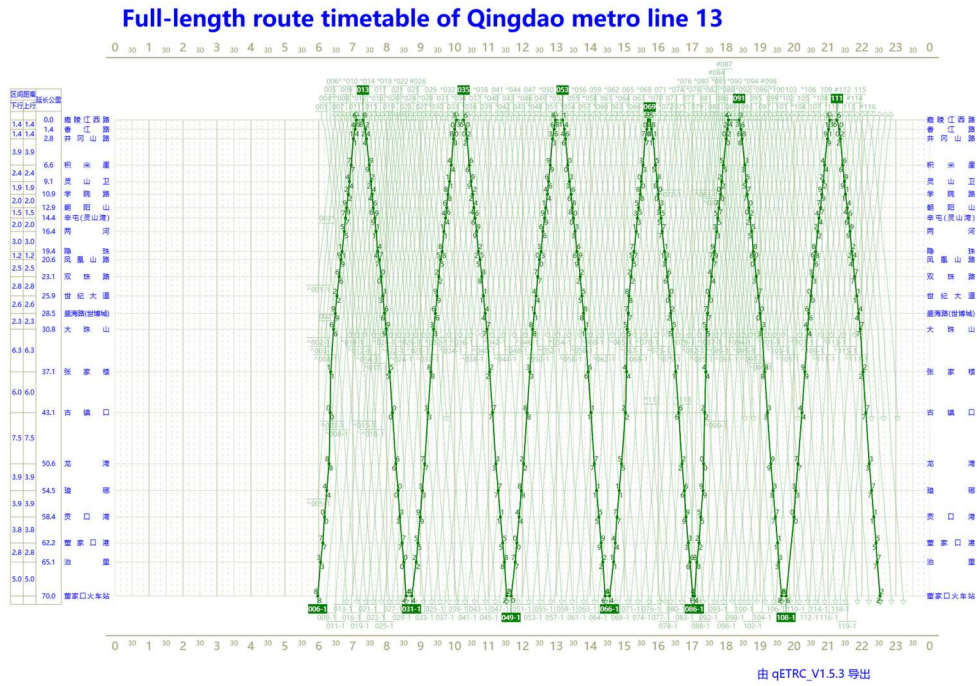


Figure 1. schematic representation of full-length route timetable of Qingdao metro line 13

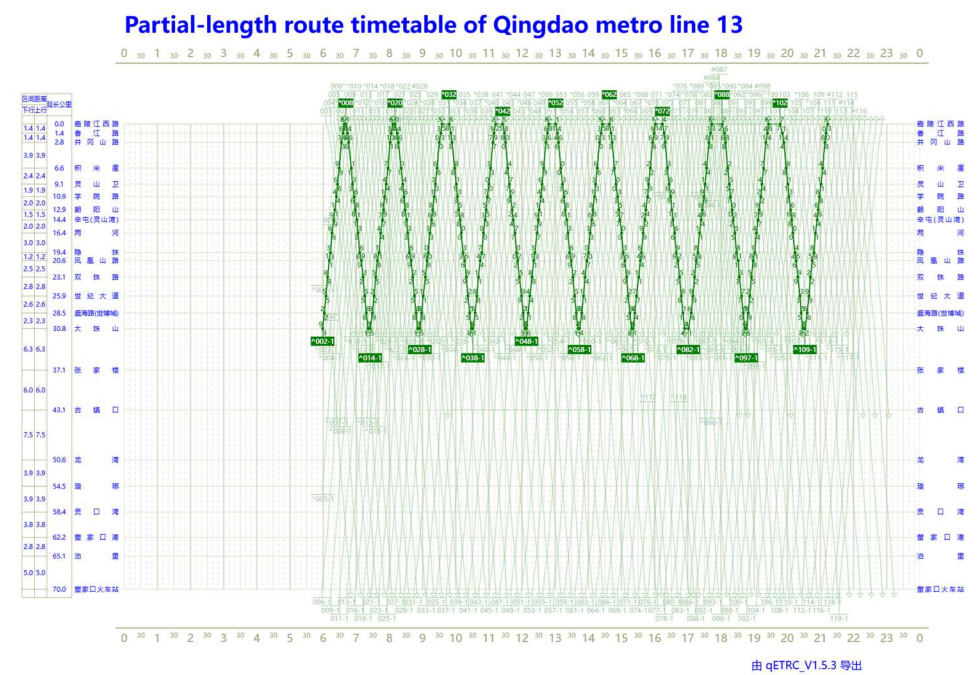


Figure 2. schematic representation of partial-length route timetable of Qingdao metro line 13

3.3.2 Metro ticket Revenue Clearing

Under the networked operation and management pattern with multiple stakeholders, how to fairly clear the passenger flows and ticket revenues among the various economic contributors is a key motivated problem with great significance. The accuracy and rationality of the clearing results can be affected by many factors. In nature, this belongs to a kind of route choice problem in the metro network [25]. For this metro ticket revenue clearing project in our OM-URT course, a sub-set of Beijing metro network is taken as a real-world study object, and the undergraduate students are required to answer the following fundamental problems:

- Self-directed and self-regulated to be a computational thinker and a digital citizen.
- Analyze the factors (certain factors, and uncertain factors) that impact the metro ticket revenue clearing.
- Survey the theory, methods and their adaptability for metro ticket revenue clearing.
- How to evaluate the precision and rationality of the results of metro ticket revenue clearing?
- Digitalized representation with directed and connected graph as well as associated information processing for the metro network with multiple stakeholders.
- How to compute the generalized passenger travel cost?
- How to determine the effective passenger routes between OD pairs?
- Analyze and evaluate the current ticket revenue clearing method, i.e. two-stage and two-proportion clearing method, of Beijing metro network.
- Try to propose and assess a new ticket revenue clearing method for Beijing metro network.

This project can assist students get a deeper understanding of the necessity, principle, theory, and methods of metro ticket revenue clearing problem via learning by doing, some examples of the implementations about the project are demonstrated as Figure 3 and Figure 4.

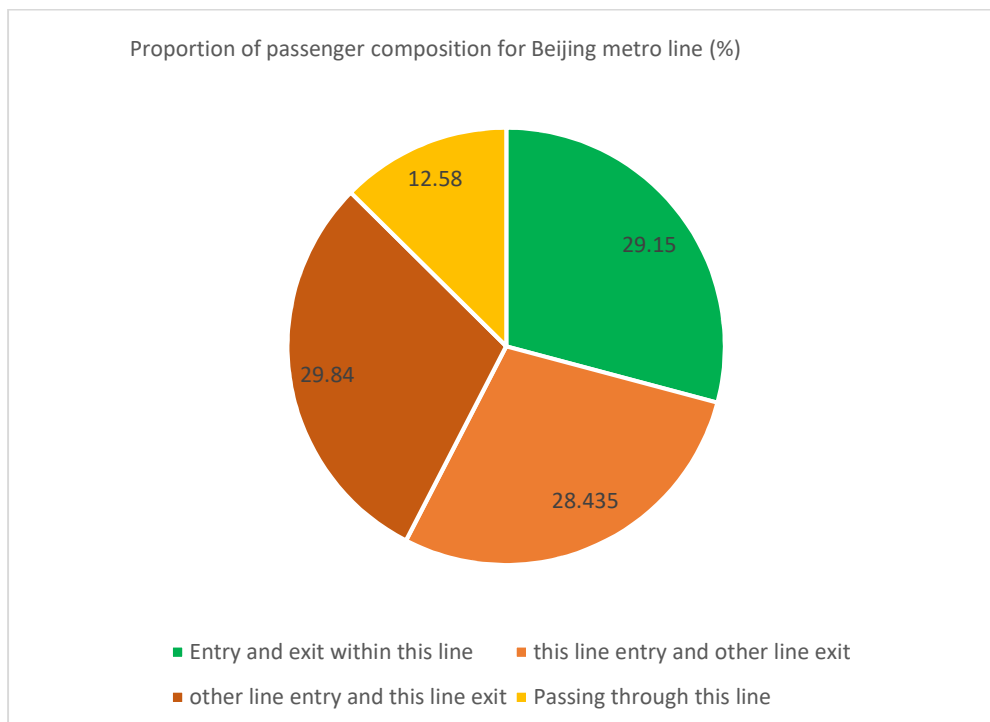


Figure 3. Proportion of passenger composition for Beijing metro line

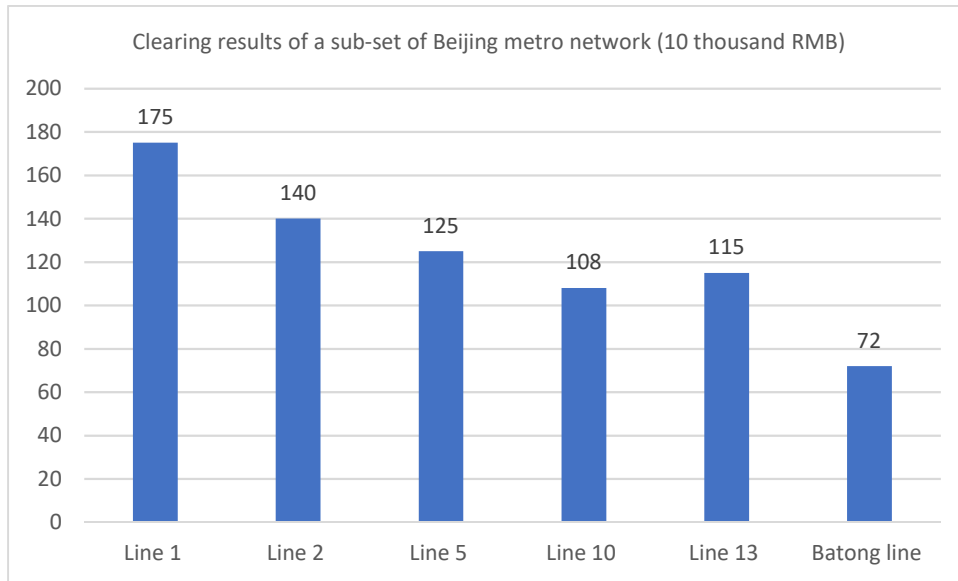


Figure 4. Clearing results of a sub-set of Beijing metro network

3.3.3 Pre-plan Compiling for Metro Passenger Flow Control

Sometimes the limited transport capacity could not match the booming passenger demands in the urban rail transit system [26], especially during peak hours. The large volume of passenger flow usually refers to the passenger volume in two cases, i.e., the volume of the passenger flow is greater than those can be accommodated by the station facility under normal operation conditions, and the volume of the passenger flow is greater than those can be undertaken by the normal passenger organization measures. The congested situations of large volume of passenger flow will lead to the delay of dwelling trains. Thus, the passenger flow control is a common method for managing the passenger flow in order to reduce congestions in the metro system, so as to ensure travel security, improve travel efficiency, and ameliorate waiting environments for passengers. For this pre-plan compiling for metro passenger flow control project in our OM-URT course, the Qingdao Metro network of China was taken as a real-world study object, and the undergraduate students are required to answer the following fundamental problems:

- Self-directed and self-regulated to be a knowledge builder, a creative communicator, and a global collaborator.
- Analyze the basic principles, the scenarios, the factors, the objectives, the index, and necessity for passenger flow control in the various levels of the metro system.
- Analyze the objectives, constraints, and solution algorithms for formulating passenger flow control model.
- Estimate the volume threshold of the passenger flow and the associated bottleneck position for metro passenger flow control.
- Determine and analyze the multilevel collaborative passenger flow control strategies [27], and the coordinated passenger inflow control strategies [28].
- Survey the methods for adaptive passenger flow control in metro network, line, and station.
- Survey the application of AI (e.g., reinforcement learning) and big data analytics on the metro passenger flow control.
- Try to compile a feasible pre-plan for metro passenger flow control for WusiSquare station of Qingdao metro network, considering service-oriented train timetabling with collaborative passenger flow control [29].

This project can tutor students to get a comprehensive understanding of the necessity, principle, theory, and methods of metro passenger flow control problem via learning by doing, some examples

of the implementations about the project are demonstrated as Figure 5 and Table 2. The notations in Figure 5 are explained in Table 2.

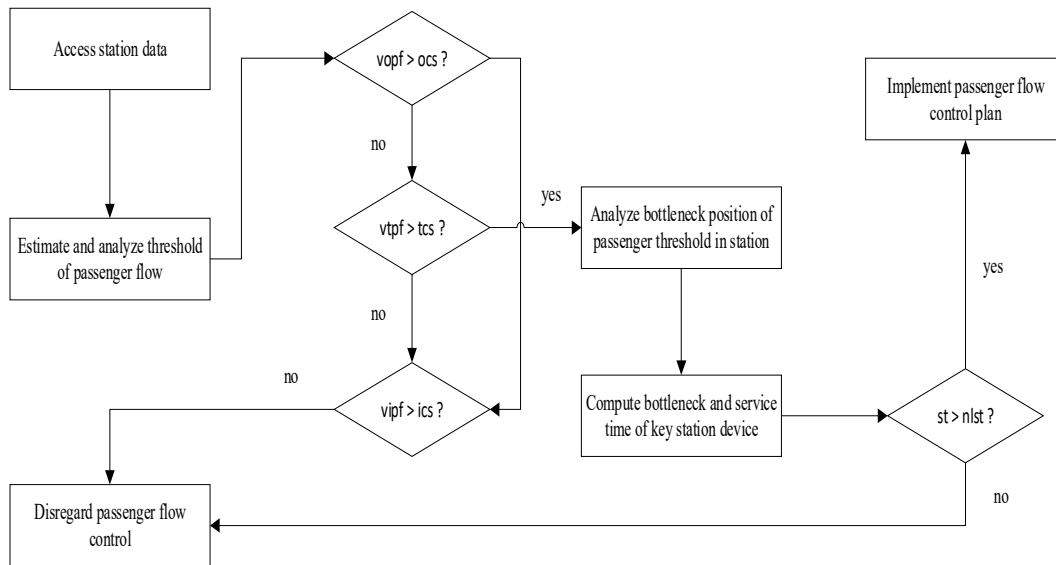


Figure 5. Decision process for passenger flow control

Table 2. Implications of the notations in Figure 5

notations	Implications of the notations
vopf	volume of outbound passenger flow
ocs	outbound capacity of station
vtpf	volume of transfer passenger flow
tcs	transfer capacity of station
vipf	volume of inbound passenger flow
ics	inbound capacity of station
st	service time
nlst	normal level of service time

4. Outcomes Assessment

For each project session, the students were divided into several working groups or teams, and each working group was allowed to designate a keynote speaker, who was allotted a maximum of 10 min to deliver and explain their complete project outcomes as a presentation. Following the presentation, the students from other teams and the subject teachers engaged in a question-and-answer session, to address and clarify any doubts or queries that arose about the theme of the projects. The overall performance evaluation of the OM-URT course consists of two parts, i.e., project-based exam (occupy 80% of the overall achievements), and statistical results of self-assessment with questionnaire rating (occupy 20% of the overall achievements).

The case study involved third-year students, aged between 19 and 22 years old, all pursuing bachelor’s scholarships. With regards to the complete ratings (associated with scores) of the project-based OM-URT course, the enrolled students are invited to anonymously rate with questionnaires (as self-assessment) responding to the three objectives about the OM-URT course. Possible scores range from 0 (“fully non-completeness”) to 5 (“fully completeness”). Data about percentage distribution of questionnaire ratings for objectives are shown for Autumn 2020 resulting from enrolled students as Figure 6, Figure 7, and Figure 8. Another group of data about percentage distribution of questionnaire ratings for objectives are also shown for Autumn 2021 resulting from enrolled students as Figure 9, Figure 10, and Figure 11. It is clear from these figures that students find the course to be valuable and that they are encouraged to learn more about OM-URT. The overall achievement degree (ranging

from 0 to 100%) of OM-URT course in Autumn 2020 and Autumn 2021 is displayed in Table 3 respectively. The achievement degree in Table 3 also shows that the project-oriented curriculum appealed to the students. They appreciated the learning by doing nature of the course and the gradually increasing level of difficulty of the projects, so as to be facilitated to get their desired study performance for the course OM-URT, which also testified the pedagogical benefit of project-based learning on OM-URT course.

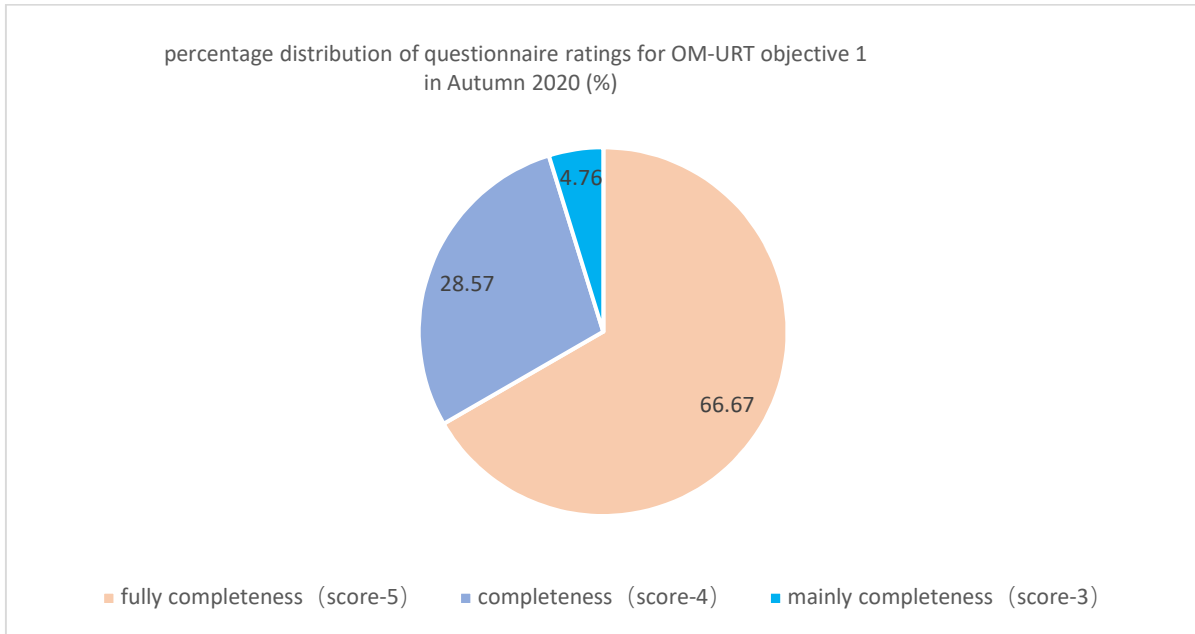


Figure 6. Percentage distribution of questionnaire ratings for objective 1 in Autumn 2020

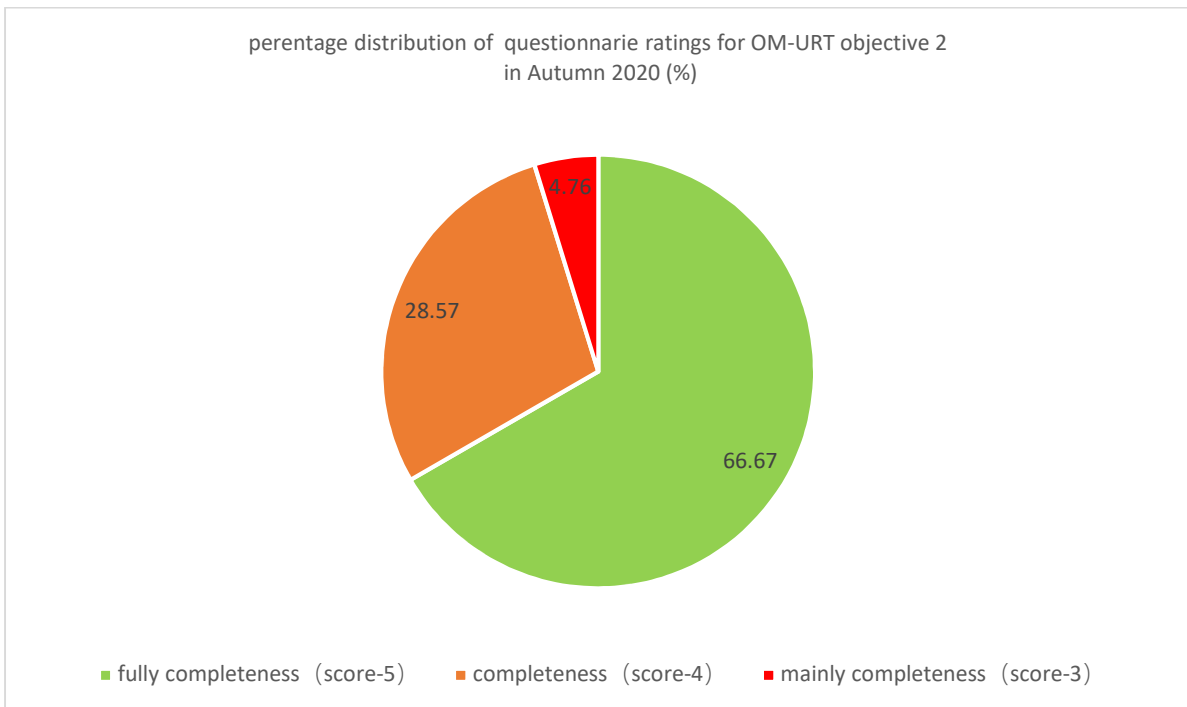


Figure 7. Percentage distribution of questionnaire ratings for objective 2 in Autumn 2020

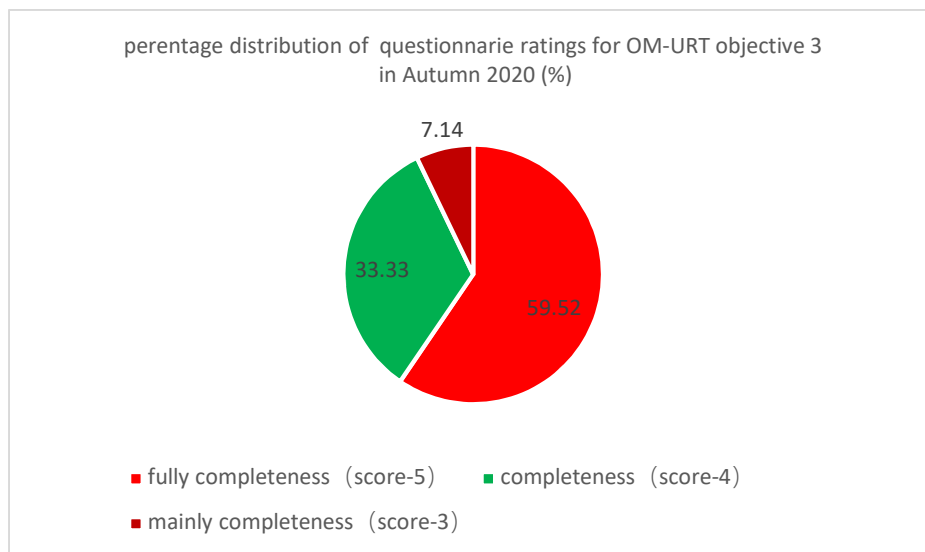


Figure 8. Percentage distribution of questionnaire ratings for objective 3 in Autumn 2020

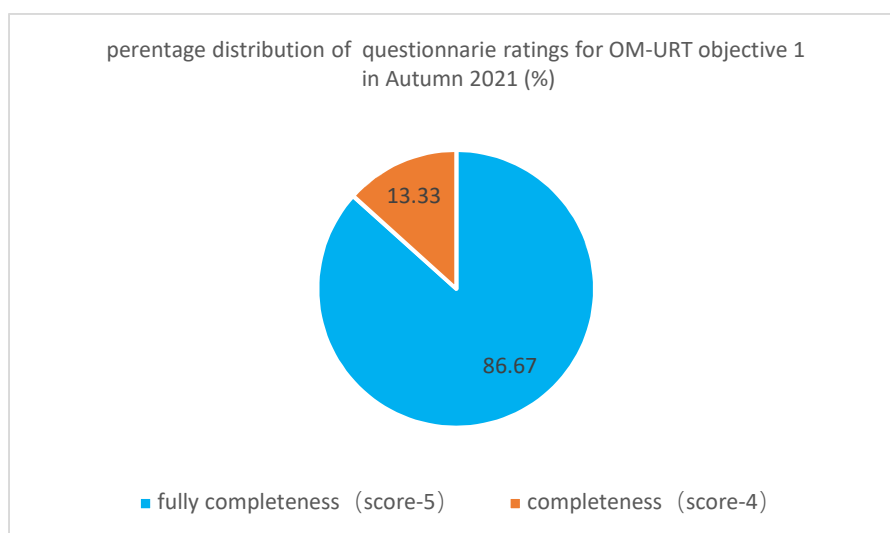


Figure 9. Percentage distribution of questionnaire ratings for objective 1 in Autumn 2021

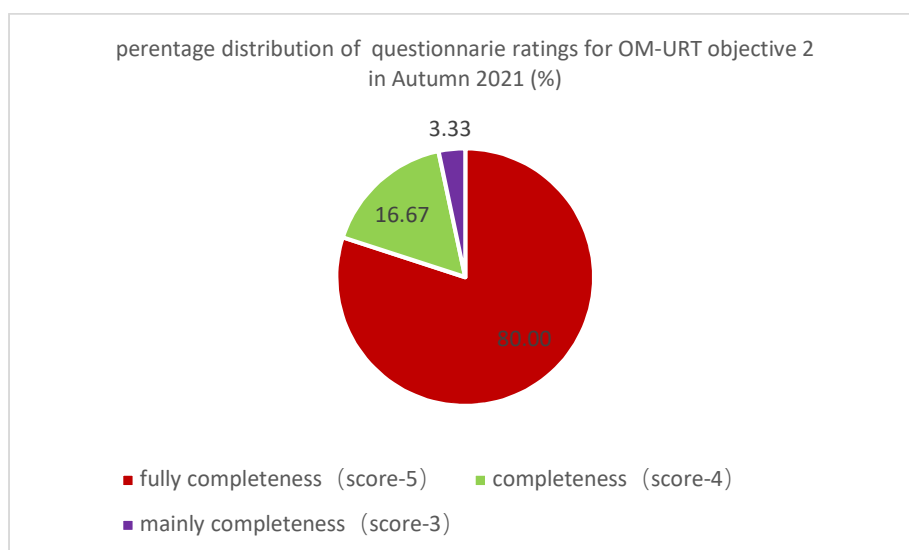


Figure 10. Percentage distribution of questionnaire ratings for objective 2 in Autumn 2021

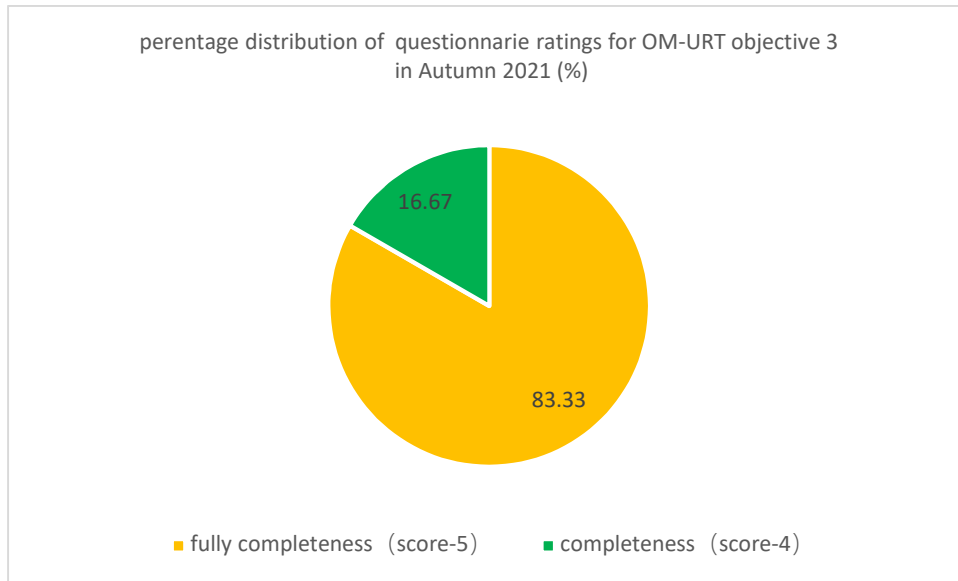


Figure 11. Percentage distribution of questionnaire ratings for objective 3 in Autumn 2021

Table 3. Achievement degree of OM-URT course in Autumn 2020 and Autumn 2021 (%)

Assessment terms	OM-URT objective 1		OM-URT objective 2		OM-URT objective 3	
	Autumn 2020	Autumn 2021	Autumn 2020	Autumn 2021	Autumn 2020	Autumn 2021
Project-based exam results	79.6	80	86.4	74	76	65
Statistical results of questionnaire rating	89.4	94	85.7	93	81.5	93
Overall achievement degree	81.6	83	86.3	78	77.1	71

5. Conclusion

The purpose of this study was to expose the project-based learning on the development of OM-URT course, with regards to three core objectives, i.e., critical thinking, higher order thinking, and complex problems-solving skills. The project-based learning method could not only equip the students with academic achievements on the course OM-URT, but also facilitate seamless cooperation and collaboration among the students under the guidance of the teachers during the development and modification of the solutions and schemes for the OM-URT projects. At the same time, project-based learning has the advantage of granting students a certain of autonomy. By engaging different cognitive levels to achieve the learning objectives, the students can improve their cognitive growth and learning performance, which makes a pedagogical sense. The course OM-URT is project-oriented and engages students with real-world study objects, the emerging technologies, and the multidisciplinary nature of the associated transportation subject. When developing the OM-URT curriculum, the challenge lies in the suitably balancing between lecture exposition and student self-guided discovery.

Regarding the AI application, it was indicated by the results that the students involved in the project-based learning for the course OM-URT not only have a better understanding about the AI knowledge (such as deep learning, reinforcement learning, and deep reinforcement learning), but also were more proficient in leveraging the AI assistants, particular in the design of the professional hints and prompts,

which lay the solid foundation for the adoption of modern AI tools with the self-directed and self-regulated capability, such as ChatGPT and WenXinYiYan.

It is crucial to highlight that educational method or technology is not only about the form of method or technology. In essence, it is the pedagogical, social, ethical, cultural, humanity, and even economic dimensions of education that the teachers/instructors should be concerned, all of which together makes pedagogical sense. Even for the project-based learning method, the associated data and coding can be taken as a relative (rather than absolute) source of support and guidance. In a pedagogically meaningful way, education is far too complicated and significant to be reduced only to project-based learning method with data analysis and algorithms. On the other hand, the project-based learning method can not only train the skill of data analysis and algorithms, but also foster capability of higher order thinking, the critical thinking, the complex problem-solving skills, and the collaboration via the teamwork, with a deeper understanding of the mechanics behind the observed results. In the future, the OM-URT associated projects can be considered to be redefined and presented by metaverses in virtual scenarios.

Acknowledgments

No acknowledgement was addressed in this study.

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