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Transforming the Future of Furniture Woodworking Instruction Through VR-Enhanced Distance Teaching During the COVID-19 Pandemic

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ABSTRACT

During the COVID-19 pandemic, distance teaching became the main solution, including for the furniture woodworking course at National Taipei University of Technology in Taipei, Taiwan, which relied on video and online software. However, this posed challenges for maintaining teaching quality and achieving objectives in technical practice courses. To address this, this study introduced remote technical guidance using VR in technical practice courses. This method combined distance-teaching and live dual-teacher broadcasts, allowing students to participate in real-time online discussions. During these broadcasts, instructors used VR to demonstrate operations on a virtual platform, explaining as they went along. Students could observe from the operator's perspective, gaining insights into furniture production processes. They also engaged in group interactions, assuming roles like technical operators, thereby mastering key furniture production concepts. This innovative teaching approach offered a solution that combined remote technical guidance with VR. It provided immediate teaching enhancements and problem-solving solutions in the post-COVID-19 era.

KEYWORDS

COVID-19, Digital Twin, Distance Teaching, Dual-Teacher Live Broadcast, Remote Technical Guidance, Tele-Education, Virtual Learning Environments, Virtual Reality

INTRODUCTION

When the COVID-19 pandemic hit, Taipei Tech faced disruptions in its practical courses, such as furniture woodworking and overseas internships. To mitigate this issue, many schools shifted to distance education methods (Iyer et al., 2020; Mishra, 2021; Tekiner et al., 2020; X. Wang et al., 2020). Taipei Tech, primarily focusing on furniture woodworking, responded to the pandemic by

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introducing remote teaching, resulting in the suspension or conversion of numerous practical courses into slide-based remote instruction.

Practical courses in furniture technology heavily depend on specific operational settings, including well-equipped woodworking studios, specialized tools, and access to essential materials such as wood, machinery, and finishing products. These conditions are crucial in facilitating students' acquisition of hands-on skills and practical experience in furniture technology, as the course content could not be adequately conveyed through presentation slides alone.

Furthermore, under the distance-learning mode, students find it challenging to understand the real-time operation of machine production from a first-person operator's perspective. This difficulty emerges due to the lack of direct opportunities for hands-on experience. This situation results in students having to piece together their understanding of overall furniture production and processing knowledge through fragmented and fragmentary slide pictures, leading to suboptimal learning outcomes.

Therefore, this study combines remote technical guidance with VR technology in online teaching; adopting a dual-teacher, live broadcast approach to provide a comprehensive perspective. Teachers conduct online teaching like game broadcasters, aligning with students' preferences to enhance engagement. Guided by teachers, students can observe the processing procedures from the teachers' perspective, engage in real-time interaction, and raise questions. Teachers can also provide direct feedback to students through the live-streaming interface.

Students actively participate through role-playing and assignments, assuming specific tasks and addressing questions related to technical operators, quality controllers, and more. Teachers use VR to illustrate concepts, complementing traditional lecture methods and fostering interactive teaching.

This innovative approach successfully overcomes pandemic-related field limitations in furniture technology courses, enabling remote participation through live broadcasts. Students gain real-time access to educators, deepening their understanding of furniture manufacturing and machine operation. The integration of VR technology adds a realistic dimension to the learning experience, fostering student participation and interaction through dual-teacher live broadcasts and group role-playing, facilitating a deeper understanding of furniture manufacturing.

Contrasting This Study With Prior Research

This study distinguishes itself from previous research by creatively integrating industry-standard remote technical guidance with VR instructional operations, while employing a unique dual-teacher instructional approach. It specifically focuses on furniture production, requiring operational demonstrations and equipment explanations. This is in contrast to past studies that primarily emphasized theoretical courses with slide presentations for remote teaching. Additionally, unlike earlier remote teaching methods that targeted single machines or tasks, this study comprehensively covers the entire concept of furniture production and its processing procedures. The innovative approach of combining lecture and technical teachers for remote live teaching, especially during the COVID-19 pandemic, represents a significant breakthrough. The application of such technology in traditional furniture production courses is exceptionally rare, setting this research apart from related studies.

LITERATURE REVIEW

The application of remote technical guidance and VR technology has become widespread in vocational training and business applications. The utilization of remote technical guidance with a digital twin has been widely implemented globally, with notable applications in product design, vocational training, maintenance, assembly, and other manufacturing operations (Buń et al., 2021; Tan et al., 2021; P. Wang et al., 2020, 2021). For instance, these technologies have been effectively employed in professional skills development, including remote education and training, remote machine repair training, and

remote medical instruction training (Morimoto et al., 2022; Nittari et al., 2022; Williams et al., 2021). The integration of remote technical guidance and VR technology has addressed challenges arising from different occupational categories, space limitations (Amores et al., 2015; Nguyen et al., 2001), and geographical barriers (Almousa et al., 2021; Galambos et al., 2015; Hollander & Carr, 2020; Linn et al., 2017; Numfu et al., 2020).

Historically, remote technical guidance primarily focused on resolving issues related to remote customers, particularly in machine operation and maintenance (Masoni et al., 2017; Mourtzis et al., 2020). It also facilitated effective communication and seamless collaboration among remote employees, partners, and customers across various industries (Amores et al., 2015; Bui et al., 2021; Gasques et al., 2021, 2021; Riva, 2000; Rojas-Muñoz et al., 2019; Rutkowski, 2021).

However, due to the COVID-19 pandemic, the teaching site for furniture woodworking has encountered limitations because of spatial constraints and geographical barriers. Fortunately, the prevalence of live media and online platforms presents educators with opportunities to redefine approaches to distance teaching for technical practice courses by incorporating remote technical guidance and VR technology (Orange & Hobbs, 2018; Widiaty et al., 2022).

Consequently, integrating remote technical guidance with a VR virtual reality environment has emerged as a potential solution to address the teaching challenges encountered in technical practice courses (Orduna et al., 2022; Villanueva et al., 2020). This approach aims to resolve the obstacles associated with conducting distance teaching for furniture-woodworking practice courses.

Revolutionizing Furniture Woodworking Education With VR-Based Remote Technical Guidance

This approach aligns with recent trends in vocational training, where remote technical guidance has gained prominence due to global supply chain dynamics (Wu et al., 2019). It offers virtual maintenance services, contributing to the digital twin concept (Beisheim et al., 2022b; Lorenz et al., 2018).

Multinational enterprises use VR environments for remote technical guidance to reduce material preparation costs and provide after-sales service and maintenance support (Beisheim et al., 2022a; Louison et al., 2017). The sales end only needs to call up the machine model specified by the customer in the VR environment and carry out maintenance teaching in remote places. Simultaneously, the client can obtain after-sales maintenance service through the screen or VR immersion participation. This user-friendly technology relies on VR screens and remote synchronization software, simplifying remote technical guidance and gaining widespread industry adoption for time and cost savings (Dalenogare et al., 2018; Errandonea et al., 2020; Geng et al., 2022; Ran et al., 2022).

Amidst the challenges posed by the COVID-19 pandemic, the adoption of remote technical guidance aligns with current educational and industry trends. This approach is particularly relevant for overseas furniture woodworking classes, catering to students aspiring to work in multinational enterprises with manufacturing facilities in Vietnam, China, Malaysia, and other locations (Susanty et al., 2020). Clients are often based in Europe, America, Japan, and other countries (Volpe, 2022). Machine maintenance relies on production technology expertise from Taiwan, Germany, and Japan.

For students venturing into the international job market, integrating remote technical guidance and VR teaching addresses the unique challenges in furniture-technology practice courses. This integration enhances their comprehension of industrial processes, fostering deeper insights into furniture manufacturing, client relations, and server operations, thereby preparing them more effectively for their future careers.

VR-Powered Remote Technical Guidance in Vocational Training and Industry

The integration of remote technical guidance with VR technology represents a groundbreaking advancement in vocational training and industrial practice (Gallagher et al., 2005; Tzafestas & Borne, 2016). VR's visual architecture, utilized for scenario simulation, has found wide application

in manufacturing (Marzano et al., 2015), design (Berg & Vance, 2017; Smparounis et al., 2009; Tea et al., 2022), and sales services (Fast-Berglund et al., 2018), significantly enhancing user convenience and intuition (Gaoliang et al., 2010; García et al., 2016; Lee, 2020; Marzano et al., 2015). In industrial settings, VR introduces the concept of digital twins (Burghardt et al., 2020; Errandonea et al., 2020; Havard et al., 2019; Pérez et al., 2020), enabling real-time control and complex production needs (Lu et al., 2020).

For instance, multinational companies can leverage remote technical guidance and VR simulations for machine tool maintenance across different countries, eliminating the need for on-site technical services. This framework allows maintenance personnel to simulate virtual machine tool maintenance via VR, reducing costs and improving collaboration with clients (Beisheim et al., 2022a), facilitating collaborative learning across regions (Beisheim et al., 2022b; Geng et al., 2022; Ran et al., 2022).

The COVID-19 pandemic has underscored the urgency and benefits of integrating remote technical guidance and VR technology, effectively breaking geographical barriers in education. In this innovative teaching approach, teachers assume the role of game operators, guiding students as spectators in a virtual environment. This method offers significant advantages over traditional distance teaching, including real-time synchronization, immersion, and telepresence (Lee, 2020; Lee et al., 2021). Educators can operate virtual machines within VR, providing real-time explanations of furniture production concepts and conducting one-to-many live broadcasts to enhance teaching efficiency. Dual-teacher live broadcasts and co-teaching foster interactivity, making distance learning engaging and informative.

RESEARCH DESIGN

This study aims to assess the effectiveness of integrating VR with remote technical guidance, coupled with dual-teacher teaching methods, in addressing the challenges related to remote teaching in practical furniture production courses during the COVID-19 pandemic. The study intends to explore the potential outcomes resulting from applying this teaching approach.

To achieve this objective, this study presents a training plan for 29 first-year students enrolled in international furniture woodworking classes (see Table 1). These students, who have successfully passed university entrance examinations and interviews, form a cohesive group with similar abilities and admission criteria. Given their status as first-year students new to furniture production, they are considered suitable participants for this experiment.

For the effective implementation of the teaching experiments, the researcher divided the 29 students from the overseas furniture woodworking classes into two groups: the experimental group, consisting of 15 participants, engaged in distance teaching with remote technical guidance and VR technology, and the control group, comprising 14 participants, received traditional on-site classroom instruction.

In the experimental group (see Figure 1), teachers delivered conceptual guidance on furniture production and processing tasks through a combination of remote technical guidance and VR technology. This involved leveraging dual-teacher live broadcasts and group role-playing to enhance student engagement. In contrast, the control group (see Figure 2) received instruction in a physical classroom, where students operated the VR system and participated in face-to-face training led by teachers. Both groups utilized VR technology to enhance learning, with the key distinction in the mode of participation and interaction: the experimental group engaged in distance teaching, while the control group attended traditional, in-person classes on-site.

Problem

The course was primarily delivered by a lecture teacher and a technical teacher. However, due to the COVID-19 pandemic, students were unable to access the school or factory to operate machines and tools, and teachers could not demonstrate the manufacturing procedures and processing concepts in

Table 1. Information on subjects in experimental and control groups

Group	Experimental (n = 15)	Control (n = 14)
Age (years)	18.53 (SD =1.06)	18.29 (SD = 0.47)
Students' learning background	Have not received any training in batch furniture manufacturing concept.	Have not received any training in batch furniture manufacturing concept.
Training Method	Learning by distance teaching.	Learning by traditional entity grouping teaching.

Figure 1. In the experimental group, students attended online classes through distance learning. The lecture teacher and the technical teacher jointly let the students participate through live broadcasts

furniture production through actual machines. This nearly halted the course entirely. Teachers resorted to distance teaching through online slides, but the effectiveness was unsatisfactory. In this context, most students were unwilling to learn (Baltà Salvador et al., 2022), making it challenging to achieve the teaching objectives of technical practice courses.

Moreover, due to the school's limited space, only simple woodworking machines could be used to teach and help students grasp the knowledge and skills of furniture production online. Without exposure to actual production line processing conditions, students only received one-sided, fragmented knowledge and experience concerning large-scale overseas processing sites and production lines. They often gained little understanding of complete furniture production and manufacturing concepts.

Considering the two issues mentioned above, influenced by the pandemic and constrained by school space conditions, there was an urgent and necessary need to invest in remote technical guidance combined with VR technology teaching introduction.

Figure 2. In the control group, students were taught the procedures and operation steps of furniture production and processing by both a lecture teacher and a technical teacher in a physical classroom

Objectives

This study aims to enhance and compare the teaching modes in Taiwan Schools during the second or third alert of the pandemic (see Table 2). The authors analyzed the changes and differences in students' learning performance and behavior patterns in curriculum interaction under two different teaching modes: (1) distance teaching and, (2) on-site group teaching through experiments. The goal was to examine the changes in students' learning and interaction.

This study presents a teaching plan that leverages VR technology and remote technical guidance, addressing the challenges faced during the pandemic when traditional teaching sites were inaccessible. It enhances student participation and interaction through dual-teacher live broadcasts and group role-playing, facilitating a deeper understanding of furniture manufacturing.

This teaching approach presents a promising step forward in the realm of distance education for practical furniture technology courses. It aims to equip students with essential skills to effectively address future challenges by introducing innovative concepts like remote technical guidance, remote support, remote operation, and online collaboration.

Type of Study

This study is categorized as an experimental research in teaching, aiming to investigate the differences in student performance and the impacts of teaching between new and traditional strategies through various remote teaching interventions.

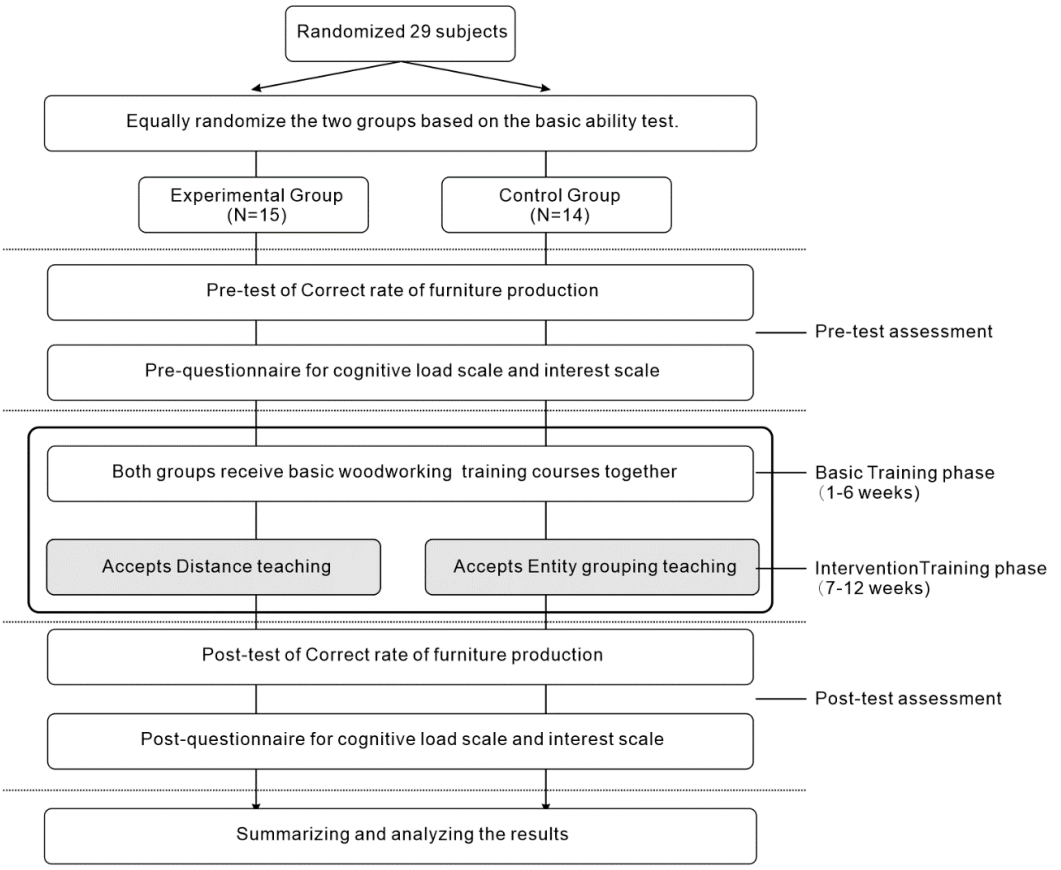
The class of 29 students was divided into an experimental group of 15 and a control group of 14 (refer to Figure 3). At the beginning of the course, both groups received basic training in woodworking (1-6 weeks). From the 7th week, the theoretical instructor, in collaboration with the technical instructor, conducted interventions in small groups (five students in each group).

Table 2. Common ways of attending classes in Taiwan Province during the COVID-19 pandemic

Teaching Methods	Distance Teaching	Entity Grouping Teaching
Class form	Students do not have to go to the school in person; they just need to attend classes remotely through the internet.	Students can attend classes in school entities, but due to the pandemic, the number of students attending classes at a time is small, about 5-8, and small classes are adopted.
Advantage	Students do not need to go to school, and the class place is flexible, effectively solving the problem caused by the pandemic or spatial distance.	Directly face-to-face, teachers can grasp the students' reactions in real-time and give direct feedback.

During the intervention stage, the students in the experimental group strengthened their experience in online processing flow and operational situations of furniture production through the teaching framework of remote technical guidance and the practical application of VR technology. The experimental group engaged in group task planning and distance teaching for furniture manufacturing methods and processing procedures.

Figure 3. The experimental flow includes phases, sessions, and experimental conditions



Teaching Strategies

Grouping Role Task Assignment and Business Responsibility Design

To reinforce the students' understanding of furniture manufacturing in the experimental group, the students participated in distance courses based on different job positions. In terms of teaching design, this plan drew inspiration from the design of business responsibilities in real furniture production. It allowed the student groups (each consisting of five people) to take on different factory roles, such as technical operators, quality controllers, process controllers, and action task recorders. These roles mirrored the responsibilities of overseas quality controllers, factory forepersons, technicians, and station leaders. This design was based on the students' future overseas work scenarios, and the students involved were expected to provide interactive feedback according to the task worksheet during the teaching process.

To enhance teaching, students were grouped in sets of students each time, and the lecture teacher and technical teacher were paired to teach them collaboratively.

By implementing the aforementioned teaching strategies and class styles, this study investigated whether the integration of remote technical guidance with VR technology could enhance the teaching of technical practice courses during the pandemic. Data on student participation, knowledge test mastery, and student satisfaction were collected to assess the effectiveness of the intervention before and after training.

Setting

Construction of VR System Based on Remote Technical Guidance

In the VR system design, the authors inspected the furniture production environment in Vietnam and divided the production process into seven stations, each involving distinct processing projects and manufacturing stages. The system underwent expert review and revisions to align with training needs. Students were assigned roles such as overseas quality control personnel, factory forepersons, technicians, and station leaders, each with specific tasks. Teachers provided task worksheets for role assignments, fostering discussion and feedback based on the scene's condition to enhance course interactivity and engagement.

Regarding platform setup, the technical teacher served as the VR remote technical guidance platform operator, requiring only one computer and a VR head-mounted display. With the establishment of the live broadcast environment and video equipment, both the lecture and the technical teacher could conduct remote online teaching, meeting the necessity for teachers to instruct remotely during the pandemic (see Figure 4).

However, students only needed to participate in the course through a personal laptop screen and remote live broadcast software (see Figure 5). In the process, students could respond according to the assigned roles, positions, and task worksheets based on the teacher's instructions. This approach enhances interactivity, allowing students to experience detailed concepts and skills related to furniture manufacturing methods and processing procedures through the teacher's first-person operator perspective.

Additionally, under the course arrangement of a dual-teacher live broadcast (theoretical teacher and technical practitioner), more concepts and practical experiences could be integrated into the VR platform based on remote technical guidance. Through the collaboration of the three parties (concept giver, technical instructor, and learning participant) (Figure 6), online live distance teaching becomes more vivid and lively. These advantages introduce new tools and methods for remote teaching, making it a new channel for educational experimentation and exploration.

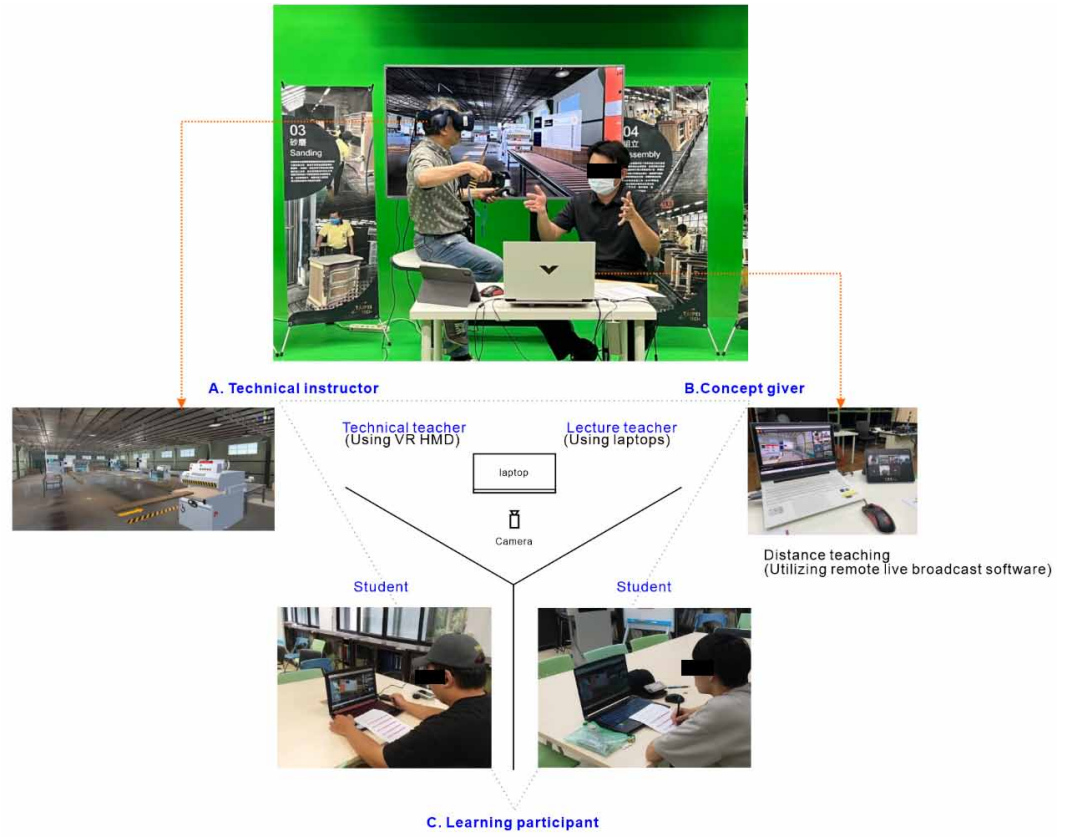
Data Collection and Analysis

Regarding the evaluation method, the plan analyzed and observed the triangular relationship (see Figure 6) between the lecture teacher, the technical teacher, and the students for the two

Figure 4. Only a computer device and a VR head-mounted display are required, along with the setup of a live streaming environment and video equipment. The lecture teacher and technical teacher can then conduct remote online teaching

Figure 5. Students can participate in the course through their personal laptops, utilizing remote live broadcast software

Figure 6. Three parties are involved in remote teaching (concept giver, technical instructor, and learning participant)



student groups (the experimental and control groups). The authors analyzed and compared the degree of: (1) the students' understanding performance (including pre- and post-tests in answering knowledge questions); (2) the interaction frequency among tripartite participants; (3) the students' behavioral responses in class; and (4) the students' learning interest and learning cognitive load scale.

This study also analyzed the two groups' learning patterns and effects based on the video recording. The authors classified different learning behavior templates and deconstructed the individual-induced teaching response through the learning behavior of various group members for discussion to understand whether this distance teaching method could benefit technical implementation courses.

RESULTS

The research results revealed no significant difference ($p > 0.05$) in the post-test knowledge and concept scores between the experimental and control groups who directly participated in the face-to-face entity grouping teaching. This finding suggests that through such teaching methods and strategies, distance teaching can yield a similar teaching effect to that of entity teaching. This learning effect is further reflected in the following data.

Students' Comprehension Performance in Answering Knowledge Test Questions

This study tested two student groups regarding their abilities and knowledge of furniture production before and after the experiment, with various test questions about batch furniture production and task operating procedures provided.

The results revealed that the correct rates of the two groups' answers before the teaching intervention were only 38.67% (experimental group) and 37.86% (control group), respectively. This indicates that there was no significant difference ($p > 0.05$) in the performance of the two groups in comprehending knowledge and concepts about the subject before teaching. They belonged to the middle and lower levels.

However, after the teaching intervention, the correct answer rates of the two student groups increased to 76.00% (experimental group) and 75.36% (control group). Both groups showed a significant improvement in post-test scores compared to pre-test scores ($p < 0.05$), with the experimental group even outperforming the control group (see Table 3). The results demonstrate that students can effectively enhance their concepts and knowledge in furniture production through teaching.

Despite learning solely through distance teaching, the students in the experimental group maintained similar learning performance to the entity teaching in the control group. This suggests that the students in the experimental group achieved good performance and improved their ability to understand knowledge and concepts with no negative impact from distance teaching. This outcome may be attributed to the unique and interactive mode of remote technical guidance, which was further reinforced through online celebrity live broadcasts and group role assignments—a mode appreciated by young students.

These findings indicate significant changes and improvements in students' learning performance, suggesting that students maintained their interest and attention in this teaching method, successfully addressing the challenges faced by traditional furniture woodworking practice courses during the COVID-19 pandemic.

The Triangular Interactive Relationship Between the Lecture Teacher, the Technical Teacher, and the Students

In contrast, traditional distance teaching methods are characterized primarily by one-way interactions through online platforms. In the past, teachers typically relied on slides for online teaching, but this method could not effectively convey operational, technical guidance, or real-time situational explanations of procedural concepts, particularly crucial for technical practice courses. For technical practice courses that are highly dependent on operational situations, students are prone to conceptual confusion, because it is challenging to understand the processing procedures, leading to poor learning results.

The innovative teaching strategy developed in this study involved lecture teachers and technical teachers co-teaching through live broadcasts of remote technical guidance and VR technology. This collaborative approach enabled comprehensive explanations of the furniture production process from various perspectives. By presenting the operation situation and program content in real-time, teachers could effectively engage students in understanding complex processing procedures, improving learning outcomes.

Table 3. Correct rate of batch furniture production in experimental and control groups

Group	Experimental (n = 15)	Control (n = 14)
Pre-Test: (20 questions in the test)	38.67% (SD = 2.28)	37.86% (SD = 1.7)
Post-Test: (20 questions in the test)	76.00% (SD = 3.0)	75.36% (SD = 3.12)

Moreover, assigning specific roles and tasks to student group members enhanced their interaction and participation. Students observed and engaged in the interaction based on their designated roles and tasks, allowing them to follow the first-person operation perspective and live commentary, facilitating a deeper understanding of the processing content and furniture production details being taught.

During the live broadcast, students find it easier to interact with teachers because of their role-playing and task execution requirements, which formed a hot spot for asking questions. The emergence of hot spots for asking questions signifies students' investment and interest in the topic, which is likely to positively affect their classroom learning performance.

In the teaching mode within the experimental group, there was a noticeable increase in the frequency and length of hot spots compared to the control group. The introduction of task worksheets with different role assignments contributed to a higher number of questions and discussions among students, fostering increased interaction and discussion. The correlation between role assignments played a role in enhancing student interaction.

The students in the experimental group focused on the content on the remote screen and exhibited a higher concentration on the teacher's teaching content due to their visual engagement and interactive nature of completing the role tasks based on the worksheet. During the teaching process, teachers engaged in dialogues and interactions with students through factory situation guidance and processing tasks in the VR environment.

Conversely, in the control group, the students' attention was mainly focused on the teacher's slide presentation at the teaching site. Students could not grasp the operational concept the teacher wanted to convey through the coherent situational picture, making it challenging for them to master and understand the concepts being discussed. The reason is why most students could only listen to the lecture one-way while trying to determine the complete furniture production process from the slides, even though the teachers explained each concept thoroughly. This made it challenging for students to understand the situational state of the concept, leading to concept fragmentation. This phenomenon is also a complex problem and teaching dilemma faced by technical practice courses that lack hands-on production and processing experiences.

Despite the control group having classes in a physical classroom, pandemic restrictions prevented large classes and hands-on machine operation in the wood factory. In the absence of machine operation, teachers could only teach theories and concepts through slides. As a result, students could only learn passively through the teacher's explanation. This approach aligned with a conventional theory class, posing challenges in capturing students' interest and diminishing interaction in teaching, particularly in technical practice courses. The traditional teaching mode adopted by the control group indirectly affected the number of times they raised questions. The lack of interest in the teaching topics and the absence of hands-on experiences made it challenging for students to pose questions. Without actual operational situations, teachers found it difficult to provide explanations with visual aids when addressing student queries.

Moreover, due to the single, one-way teaching methods, students raised their questions often after a concept was taught. This lack of real-time interaction hindered the formation of a dynamic dialogue between teachers and students, making it difficult to create a vibrant exchange of questions and discussions. Furthermore, due to the one-way teaching method, teachers were busy clarifying the background of the students' questions. A notable limitation was the absence of real situational or operational visuals explaining the concepts related to furniture production equipment and processing flow.

In contrast, the experimental group, utilizing remote technical guidance and VR live broadcasts, facilitated more active participation in the dialogue due to their ability to see the processing situation and operation content. Therefore, it was easy for them to have interaction and dialogue, and this enhanced interaction became a key factor in creating hotspots for exchange, discussion, and questioning.

Behavioral Responses of the Two Groups of Students in Class

In analyzing behavior responses, the authors observed heightened enthusiasm among students in the experimental group. This enthusiasm stemmed from the unique combination of distance and live teaching, wherein both the lecture teacher and technical teacher played integral roles. The distinct class environment, characterized by assigned work tasks and roles, transformed the teaching approach into an experience reminiscent of a factory tour or situational exploration. The direct interaction between the lecture and technical teachers facilitated a first-person perspective engagement. Using the VR with dual-teacher live broadcasts, students felt as if they were present in a virtual furniture factory, enhancing their intuitive understanding of furniture production.

Additionally, this teaching method facilitated direct student participation in questioning during the dialogue between the lecture teacher and the technical teacher. The technical teacher could promptly adjust the VR viewing angle and provide explanations, ensuring a coherent concept explanation and communication process. Hence, students' participation and interactive dialogue frequency were notably high, establishing a vibrant environment conducive to asking questions.

In contrast, the students in the control group were divided into classes using a slide show. Although the VR system was available for individual operation at the teaching site, the teacher's explanations were largely unidirectional. Most students listened to the lecture in one direction without significant interaction, making it challenging to inspire interest and establish a hot spot for interaction, discussion, and questioning in the technical practice class. Therefore, most students in the control group were only interested in the individual operation of the VR system. Since the VR system had to be operated sequentially, students not actively engaged had to wait, resulting in inefficient use of time during VR teaching.

Clear distinctions are evident in the behavioral responses and the status of hot spots for asking questions of the two groups. The students in the experimental group were livelier because they participated in the course at a distance. This shift in behavior can be attributed to the cultural tendency among Taiwanese students, who often feel hesitant to engage in face-to-face interactions with teachers and may be reluctant to pose questions. However, in the distance environment, they exhibited greater courage in asking questions without fear, just like through online virtual agents.

Conversely, students in the control group were apparently afraid to talk or less likely to ask questions. Rather, they mostly listened to the teacher's lectures and remained silent during the class, a common trait among Taiwanese students. Unless the teacher allows them to ask questions, most are reluctant to express their personal opinions, making it challenging for them to fully engage and concentrate on the class content.

Students' Learning Interest and Learning Cognitive Load Reflection

Degree of Learning Interest

The learning interest performance was assessed by measuring the learning interest index before the experiment, revealing a score of 5.33 for the experimental group and 5.0 for the control group (on a scale of 1-7). No significant difference ($p > 0.05$) was observed between the two groups in their pre-test scores (Table 4).

Following the teaching intervention, the learning interest index increased to 6.27 for the experimental group and 5.79 for the control group (on a scale of 1-7). The students in the experimental group scored significantly higher than those in the control group ($p < 0.05$), indicating a greater level of interest in their learning. These findings are supported by the data collected on their learning interest.

Moreover, implementing technical courses involving VR applications under the guidance of remote technology can not only align with curriculum requirements, but also enhance students' concentration and interest in the courses.

The rationale behind this lies in the distance teaching design, which included the course arrangement of role assignment and task observation, the integration of dual-teacher (lecture teacher

Table 4. Pre- and post-test of learning interest scale on subjects in experimental and control groups

Group	Experimental (n = 15)		Control (n = 14)	
Learning interest scale (Score from 1 to 7)	Pre-test	Post-test	Pre-test	Post-test
	5.33	6.27	5.0	5.79

*1 to 7 means from no interest to very interested

and technical teacher), and the utilization of online live broadcast modes, popular among young learners. After the teaching sessions, the authors interviewed the students to assess their interactions during the distance learning period. They found that in this environment, students were more willing to engage with the teachers, and the teachers found it easier to explain the reasons for problems through VR demonstrations. These comprehensive observations revealed that this approach had formed a teaching thrust and learning pull, enhancing students' learning interest and concurrently the formation of hot spots for questioning.

While the students in the control group engaged in direct interaction during entity teaching, the nature of technical practice courses prevented them from physically entering the factory due to COVID-19 restrictions. They could only adopt small class groupings. Due to the limited number of VR equipment, they could only use it sequentially, which led to students' stagnation or one-way teaching most of the time, where it was difficult to inspire the students' interest.

Therefore, the teaching method adopted in the control group could not attract students' interest through one-way listening. The waiting period accentuated student boredom, as they lacked task requirements.

Degree of Learning Cognitive Load

In terms of cognitive load, the two groups found it challenging to master the knowledge concept of furniture production and manufacturing procedures before the experimental intervention. The cognitive load index before the experiment was 5.4 (experimental group) and 5.5 (control group) (scale 1-7), with no significant difference ($p > 0.05$) between the two groups in their pre-test.

After the teaching intervention, the cognitive load index decreased to 3.67 (experimental group) and 3.86 (control group) (Scale 1-7). Notably, the students in the experimental group were quite happy in the learning process, marked by the formation of hot spots for discussion and questioning, resulting in a significantly lower cognitive learning load among the students in the experimental group ($p < 0.05$).

Through long-distance technical guidance, VR, and dual-teacher teaching, coupled with meaningful task assignments and role assignments, the learning process of the experimental group students was more relaxed, and their cognitive learning load was reduced (see Table 5).

DISCUSSION

The primary objective of this teaching method was to address the suspension of practical courses in the teaching field due to the pandemic. The operational concept of furniture manufacturing and

Table 5. Pre- and post-test of cognitive load scale on subjects in experimental and control groups

Group	Experimental (n = 15)		Control (n = 14)	
Cognitive load (Score from 1 to 7)	Pre-test	Post-test	Pre-test	Post-test
	5.4	3.67	5.5	3.86

*1 to 7 means from simple to very difficulty

processing tasks was introduced by leveraging the remote technical guidance platform. Subsequently, through the realistic situation presented through the use of VR technology allowed both the lecture teacher and technical teacher to collaboratively deliver classroom lectures and operational explanations, establishing an interactive mechanism of dual-teacher live broadcast and joint teaching.

At the same time, this teaching strategy also introduced the technical methods commonly used in the industry, integrating innovative technology and teaching practice. This significantly changed the teaching method, especially in a traditional furniture and woodworking course.

Historically, these courses predominantly followed the apprenticeship system, emphasizing manual work and technical proficiency. With the changing times and the industry's evolution, teaching sites must adapt by integrating digital machines. The concepts of collaboration, remote communication, and remote operation have become the industry norm, and the use of digital processing machines is now a universal trend. Therefore, students in the furniture industry and special classes are no longer solely trained as carpenters; they must understand new technologies and methods within the industry, such as remote technical guidance via VR. This adaptation allowed overseas manufacturing companies to maintain communication amid the pandemic and overcome the limitations of distance. Moreover, the upheavals in teaching induced by the pandemic ushered in new prospects and opportunities, particularly with the integration of remote technical guidance and the application of VR technology.

Therefore, applying remote technical guidance combined with VR technology has become an effective and innovative teaching strategy. This approach empowers students to address space barriers and master the furniture manufacturing methods, processing procedures, and quality management of furniture production online through the situational operation of a VR virtual production line. The effectiveness and performance of training can be attributed to the following reasons.

First: The application of remote technical guidance combined with VR technology architecture strengthens on-the-spot learning and promotes a sense of participation from the first-person perspective required for distance teaching.

Overseas students enrolled in furniture woodworking classes at the University of Taipei Tech were remotely instructed in furniture-woodworking practice courses. In response to the demand for distance teaching under the influence of the pandemic, a teaching design incorporating a VR system based on remote technical guidance, was innovatively developed to achieve on-the-spot learning and a sense of participation from the first-person perspective, which is essential for distance teaching and learning of furniture technology practice courses.

VR technology aligns with the operating requirements and teaching characteristics integral to furniture technology practical courses, replacing the limited scope of traditional distance teaching, which is reliant solely on slide teaching. The teaching structure of VR technology allows students to virtually accompany the technical teacher as they navigate the field and observe the operation of processing stations from the perspective of first-person operators. During the technical teacher's operation and explanation of the processing machines at the stations, the lecture teacher can provide additional information on the side, promoting a vivid and lively teaching and interactive process. This mimics a real-time scenario, allowing students to operate processing machines themselves, making the learning experience both intuitive and engaging.

Second: The interaction of distance teaching in technical practice courses is strengthened using dual-teacher teaching and live broadcast.

Students can watch online simultaneously through the dual-teacher and live broadcast method, thereby enhancing teaching efficiency. Additionally, in the teaching process, students can improve their interaction through group activities and role-playing tasks. Teachers can also determine whether

the students understand the teaching content and identify any teaching blind spots in real-time from the course.

This interactive architecture combines remote technical guidance, VR realistic scene reproduction, and the media-teaching format of live broadcasts. These situational settings align with the information exchange preferences of younger generation students, highlighting this teaching plan's innovation and creativity.

Third: The application of remote technical guidance combined with VR technology conforms to technical practice courses' operating situational needs and teaching characteristics.

Reproducing the telepresence of machine operation and conveying the procedural nature of production and processing pose significant challenges in distance teaching for furniture technology practical courses. However, these requirements are the focal points of furniture technology practical courses. Unfortunately, the influence of the pandemic and the limitation of distance teaching have forced a halt in the courses or the use of inappropriate teaching materials, significantly reducing the teaching goals and characteristics related to machine operation and actual program drills in furniture technology.

However, the teaching method employed in this study, which integrated remote technical guidance with VR technology, introduces industry-relevant technical concepts into course instruction. Utilizing familiar live broadcast tools for both teachers and students and complementing them with the situational simulation of VR, the technical teacher assumes the role of a game master, while the lecture teacher becomes the live broadcast master. This approach adeptly integrates the complete overseas factory production line into distance teaching.

This application, which combines VR-based distance teaching and dual-teacher live broadcasts, is an innovative method that provides a new opportunity for the teaching industry. It directly aligns with the teaching characteristics of furniture and woodworking departments, where explaining machine operation and experience the on-the-spot environments are essential. Teachers play a crucial role in cultivating interest in learning, guiding them through knowledge and technology via situational participation and operational experience. This approach fosters familiarity and proficiency in skills, contributing to improvements in teaching knowledge, affection, and skills.

Achieving these goals is challenging for traditional distance teaching, especially relying solely on slide teaching. In the distance teaching application of furniture technology practical courses, this technology can achieve relatively suitable teaching performance with minimal hardware construction. The goal is not to increase teachers' excessive burden and technical difficulties, but rather to address the challenges in traditional furniture practical courses through simple technology integration.

Fourth: The concept of remote synchronization guided by remote technology is suitable for the remote teaching explanation in the teaching field.

Remote technical guidance, as its name implies, enhances learners' telepresence and operational skills in different places by combining remote methods with VR technology. In many cases, remote technical guidance is carried out by video. In this setup, teachers operate through tangible objects, and students have the equivalent tangible objects. Both parties can engage in synchronous operations in different places through video connection (similar to an online cooking classroom, teachers and students have similar materials and equipment, and both open a video connection for synchronous operation). However, in a furniture manufacturing and prototyping environment, multiple types of essential machines operate harmoniously. Employing the aforementioned methods in a spatial and practical teaching context becomes challenging when dealing with many machines. Fortunately, these

challenges have been addressed and resolved in relevant case studies abroad (Geng et al., 2022; Ran et al., 2022).

For example, tubing operation technicians deliver lectures on VR virtual tubing operations overseas (Wanasinghe et al., 2020). In contrast, local technicians engage in entity tubing operations simultaneously because large-scale processing production lines, or factory environments, are characterized by numerous operation links, intricate processing flows, and various processing machines. It is a labor-saving method that offers an efficient solution in simulating the operating environment of instructors by remote technical guidance combined with VR technology. VR's ability to accommodate a vast digital virtual machine platform model, coupled with its capacity to provide a sense of presence in the operating environment, renders it highly suitable for technical practice courses heavily reliant on practical experience.

Even with the implementation of VR technology, co-workers from different locations can engage in technical operations, immersing themselves in a shared virtual world simultaneously. This facilitates an interactive mechanism involving synchronous communication and immersive training across different locations. Therefore, applying this method addresses the distance-teaching problem of furniture technology practical courses during the pandemic. Furthermore, it introduces industry-standard communication methods into the teaching courses, allowing students to better understand the application of this technology and method. It enables students who are about to invest in overseas furniture manufacturing in the future to proactively master and experience such communication methods and scenarios, thereby preparing them for future challenges.

CONCLUSION

This study examines whether the vocational training framework involving the integration of emote technical guidance with VR technology can improve the teaching challenges that happened in furniture technology practical courses due to the COVID-19 pandemic. The shift to remote teaching disrupted traditional teaching methods, prompting the exploration of alternatives such as remote technical guidance combined with VR technology to replace the traditional one-way online lecture method. This new teaching strategy has undergone testing and verification, specifically in the context of practical furniture technology courses.

This study observed and designed the interaction triangle involving the concept giver, the technical instructor, and the learning participants. Experimental research and design were conducted under two different teaching conditions to understand the performance of teachers and students in the course interaction within the framework of remote technical guidance. The study aimed to evaluate the effectiveness of students in various tasks and learning activities.

Furthermore, this study introduced media formats, such as live webcasts and online games, which are popular among young learners, seamlessly integrated with VR technology to achieve realistic situational interaction similar to online games. Live broadcast methods, familiar and preferred by young people, were used to assist the lecture teacher and the technical teacher in capturing the attention of young students in distance teaching.

Within the framework of remote technical guidance, this teaching plan demonstrates that integrating VR technology can enhance students' enthusiasm for learning and interaction in distance teaching. It establishes an interactive mechanism involving group activities and role-playing under dual-teacher live broadcast conditions, guided by task questions corresponding to each station. This approach yields improved teaching outcomes and heightens interaction during classroom operations.

In terms of teaching, this study identified the following outcomes:

1. Increased frequency of interaction between teachers and students and the number of questions.
2. Formation of hot spots for questions related to the teaching and production practice of specific stations.

3. Maintenance of a sense of presence and operability similar to a real processing site for students under VR remote guidance, from the perspective of the operator.
4. Clear understanding by students of the principles of machine operation or the steps and details of processing operations under the guidance of the lecture teacher and the technical teacher.
5. Production of conceptual correspondences for specific furniture production and processes by students, achieving outcomes that were challenging to attain in traditional distance teaching.

This study further revealed that remote technical guidance and the introduction of VR technology could help students obtain a smoother learning experience in furniture production and manufacturing. Students gained insights into the operation of specific machines and tools, as well as an understanding of the processing procedures at multiple stations. The live broadcast interaction facilitated by dual teachers enhanced the synergy of teacher and technician collaboration, forming an interactive triangle among concept educators, technical educators, and learning participants, generating diverse feedback from all three parties.

This feedback shaped a comprehensive teaching mode and learning framework, culminating a VR vocational training framework based on remote technical guidance specialty. This framework represents a course application grounded in both theoretical foundations and practical operations.

Regarding the teaching application, this plan encompasses the instructional design and strategy application of remote technical guidance, considering the interactive relationship between teaching and learning and the guidance skills required, especially given the unique nature of furniture technology practical courses.

The pandemic underscored the inadequacies of traditional distance teaching methods in meeting teaching requirements. However, the situation led to a stronger emphasis on collaboration, remote communication, and remote operation in the field of remote technical guidance. This shift was particularly crucial and noteworthy in the context of teaching courses, especially when it comes to overcoming challenges encountered in traditional furniture-woodworking practice courses. Integrating VR technology made remote technical guidance a valuable solution that effectively addressed the teaching predicament.

Notably, contemporary students exhibited a strong affinity for online media in their studies. The live broadcast method can potentially revolutionize existing teaching methods and attract students' attention. The combination of remote technical guidance and VR technology, along with the online live broadcast teaching method of dual teachers, is bound to transform the long-distance teaching methods of furniture technology practical courses in the past, and address the interruption of these courses due to the pandemic.

The introduction and remote guidance framework have gained an innovative opportunity in research and teaching practice because of the pandemic's impact. Despite the resumption of in-person teaching for current courses, the teaching industry must remain prepared to adapt to the unpredictable nature of the pandemic. Therefore, under the impetus of the industry's usual remote collaborative operation and remote technical guidance, introducing such teaching methods and technologies has brought new ideas and excitement into the learning experiences of students in special classes. These technical platforms, which used to exist only in specific occupations (such as remote aircraft maintenance and remote medical guidance), have now made their way into the traditional furniture woodworking profession, marking a novel attempt and innovation in teaching methods, irrespective of the pandemic's return.

While this teaching approach may have limitations in providing hands-on feedback, it represents a significant step in distance education for practical courses in furniture technology. It prepares students for future challenges by introducing innovative concepts such as remote technical guidance, remote support, remote operation, and online collaboration.

LIMITATIONS AND FUTURE STUDY

The integration of VR applications into remote technology-guided teaching has a positive impact on technical practice, but is not without limitations. Somatosensory feedback for operational tasks remains unattainable for students. However, in distance teaching, the emphasis is placed on explaining concepts related to large-scale furniture. While developing a VR system is time-consuming, it is justified in enhancing students' comprehension of online production. Managing large class sizes in distance teaching poses challenges, but the potential solutions may be found in future advancements in VR technology. Challenges such as poor online environments or slow network speeds can disrupt live sessions, but improved hardware and networks can resolve these problems. Despite these limitations, these teaching methods retain high value, particularly during a pandemic, offering various simultaneous teaching possibilities.

AUTHOR NOTE

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