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The Empirical Research on University Instructors' Competencies in Virtual Reality Environment from the Perspective of Students' Learning Experience

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Abstract: *The integration of virtual reality (VR) and education is a key way to realize the modernization of higher education. Instructors' competencies directly affect students' learning experiences and achievements. Based on the IBSTPI competency standards compiled by the International Board of Standards for Training, Performance, and Instruction (IBSTPI), this study developed an instructors' competencies scale suitable for the VR environment from the perspective of students' learning experience and conducted an empirical research on the current situation of instructors' competencies in VR environment. The scale categorizes of instructors' competencies included six dimensions: establishing and maintaining learning motivation competencies, expressing competencies, questioning competencies, giving feedback competencies, promoting knowledge consolidation competencies, and facilitating knowledge transfer competencies. The results showed that the competencies of university instructors in VR environments have been in the upper middle level and there were differences in the level of instructors' competencies in different dimensions. Necessary is for universities and instructors to optimize the cultivation of instructors' competencies in VR environment.*

Keywords: virtual reality environment, instructor competency, learning experience, higher education

1. Introduction

To build a learning society with lifelong learning for all, promoting the digitization of education is one of the indispensable means (Ministry of Education, 2021). Vigorously implementing the strategic action of education digitization is important. With the rapid development of science and technology, VR as a new technology form with unique advantages such as immersion, interactivity, and multi-perception (Hua et al., 2021) can provide new opportunities for promoting education digitization. The American Association for Higher Education Informatization pointed out in the "2022 Horizon Report (Teaching and Learning Edition)" that as we have entered the era of 5G, and expect a quantum leap in connectivity with experiences including augmented reality (AR), virtual reality (VR), and so on (EDUCAUSE, 2022). In 2022, the Ministry of Education and other five national departments of China jointly issued the "Action Plan for the Integration and Development of Virtual Reality and Industry Applications (2022-2026)" (Chinese Government, 2023). The integration of VR and education is the key to realize the modernization of higher education, and VR is a magic weapon to recognize the high-quality development in Chinese higher education.

New challenges to university instructors' competencies have been posed with the continuous integration of VR and education. The new teaching environments have created a different way of teaching content presentation and concepts. For example, with the support of VR, the teaching environment has been broken down through the traditional physical space, and the richness of three-dimensional educational resources requires instructors to have capability of utilizing appropriate teaching methods. This leads to the increase of instructor-student interaction that requires instructors to have effective expression and questioning competencies. The educational practice is optimized from the traditional case-based teaching methods to the methods integrating multiple knowledge and virtualization (Hamilton, 2021; Du, 2021). Liu et al. (2016) put forward the action topic that traditional pedagogy and traditional teaching concepts needed to be optimized urgently in the VR environment. Instructor competency is one of the core components of instructors' professional competencies, and it directly affects the quality of talent training (Han & Ge, 2018). The problem of incomplete mismatch of instructors' competencies in the virtual teaching environment can affect student engagement and learning experience, further influencing learning achievement.

Although there have been plenty of studies on the application of VR technology in higher education, most of them focus on the study of students' learning achievement, and there have been few studies on the role change of instructors and their professional development in VR environment. What is not clear is which competencies promote learning effect. In addition, there has been a lack of measurement tools for instructors' competencies under the characteristics of VR environment. In this regard, carrying out research on the instructors' competencies suitable for the VR environment to promote the reform of teaching mode and learning experience in higher education should be performed. Therefore, the purpose of this study is to construct a theoretical framework reflecting university instructors' competencies in VR environment, develop reliable scientific measurement tools and analyze the characteristics of instructors' competencies

under different dimensions, so as to provide suggestions for the development of instructors' competencies in VR environment, and help instructors to improve their competencies in VR environment. At the same time, also conducive is for education managers in higher education institutions to comprehensively evaluate the quality of teaching and learning in a VR environment, as well as strengthen and adjust the management process.

2. Literature Review and Theoretical Foundations

2.1 The Landing of VR in the Field of Education

Ivan Sutherland (1963) first proposed the theory related to virtual reality that virtual reality technology provided individuals with a variety of sensory stimulation, which in turn produced immersion. Individuals can also interact with things in a virtual environment. After more than 20 years, Lanier, the founder of VPL (Virtual Programming Languages), brought virtual technology back into the public view and proposed the concept of " Virtual Reality (VR) "(Lewis, 1994). Dionisio et al. (2013) believed that VR was an environment simulated by computer output and individuals could interact with it. With the continuous development of science and technology, VR is gradually becoming a new field of science and technology, with a more accurate concept. Institute of Electrical and Electronics Engineers (IEEE) defined a virtual reality environment as a highly realistic computer simulation environment in terms of vision, hearing, touch, smell, and taste (Huang, 2017). In this study, the virtual reality environment is a new practical technology that integrates multiple disciplines to form a real or real-like environment generated by a computer, which learners and teachers manipulate and interact with the help of equipment.

Currently, the research on VR in education mainly focuses on four different areas. First is the research on advantages of VR in education, including the promotion of learning achievement, and the advantages of application in different education fields and disciplines. For example, examining whether VR can reduce cognitive load and enrich the learning experience (De Carolis et al., 2019), bringing a high sense of immersion, thereby promoting a strong sense of presence among students and improving learning achievement is done (Dan & Reiner, 2018). Second is the use of comparative studies of education supported by VR and traditional ways. For instance, Zheng (2021) and others conducted a meta-analysis of the research on collaborative learning experiments and quasi-experiments supported by VR between 2007 and 2019. The results showed that the experimental activities supported by VR were more effective than traditional experimental activities, and had a moderate positive impact on students' cognitive level, skill level and emotion. Through experiments, Lopez et al. (2021) found that students who used VR performed better in identifying structures and describing functional meanings. Dan and Reiner (2018) demonstrated that compared with the plane environment, students have had lower cognitive load in the virtual environment with stereo vision. Third is the research on the development of VR education resources. The development of educational resources supported by VR is the basis for promoting the integration of VR and education. Several scholars have developed educational environments, practice platforms, and curriculum resources. For example, Zhou et al. (2018) created an educational

application based on HTC Vive (headphones that provide an immersive experience) in a VR environment. Fourth, many researchers have studied the relationship between variables in the VR environment and the impact of VR on learners. For instance, Makransky and Lilleholt (2018) used a structural equation model to study how the level of immersion of 104 college students in a virtual reality environment affects the results of perceptual learning. Shin (2017) explored students' motivational visibility and tested how it affects students' acceptance of learning environments based on VR.

2.2 Research on Instructor Competency

As an important subject of teaching and learning, strengthening the improvement of the competencies of instructors is the theme of the development and construction of universities. The existing research on instructors' competencies can be divided into two aspects. One is the research on the structure of instructors' competencies. In the early 1980s, with the establishment of teacher specialization, the instructors' competencies have been widely concerned by experts and scholars. Simpson and Smith (1993) expanded the instructors' competencies into six dimensions based on the attributes of university instructors, including planning skills, scholastic skills, presentation and communication skills, evaluation and feedback skills, management skills, and interpersonal skills. Guasch and other researchers (2010) pointed out that university instructors should have a planning function, social function, instructive function, technological domain, and management domain. Selvi (2010) re-divided instructors' competencies into nine dimensions as field competencies, research competencies, curriculum competencies, lifelong learning competencies, social-cultural competencies, emotional competencies, communication competencies, information and communication technologies competencies (ICT), and environmental competencies, which was called the general standard of instructors' competencies. In China, scholars such as Hu (2021) defined the structure of instructors' competencies as teaching design ability, implementation ability, reflection ability, evaluation ability, management ability, information technology, and teaching integration ability.

Furthermore, as the research on instructor competency deepens, more researchers recognize that the enhancement of instructor competency is the guarantee of teaching quality. Therefore, many studies have begun to investigate how to cultivate instructors' competencies. The University of Oregon launched the Teaching Effectiveness Program (TEP) mainly in the form of workshops, seminars, and dialogues to improve instructors' competencies (Duo & Zhong, 2017). University of California, Berkeley, as a model of faculty teaching competency development in the United States, has developed instructors' competencies mainly by building consultation mechanisms, interactive systems, and teaching incentive programs (Distinguished Teaching Award, 2015; Faculty Guide to Campus Life, 2015). Chen and Xu (2022) developed the research and improvement of teaching ability development strategies for college teachers driven by artificial intelligence from different levels.

2.3 Research Related to Instructor Competency in the VR Environment

The virtual reality environment has core elements such as immersion, interactivity,

and presence (Reen et al., 2022), which is conducive to the development of high-quality education and teaching, but also poses new challenges to instructors' competencies. The role of instructors in VR environment has changed such as from the role of implementing teaching content and grasping and controlling teaching activities to the role of leading the classroom and designing the system content, which mainly includes teaching designer, supervisor, guide, and teaching aid. A great deal of relative studies in the VR environment has paid much attention to instructors' attitudes, training system construction, instructors' roles, etc. For example, Huo and Yue (2021) surveyed instructors who had used the mechanical virtual experiment platform, and the results showed that most teachers have had positive attitudes toward the convenient characteristics of the platform, such as multimedia resources, friendly interactive interface, and collaborative communication tools. Ning (2021) built a music network teaching platform based on VR. The operating and interactive interface of this platform provided teachers with a convenient way to organize teaching, and teachers could publish new teaching contents at any time and organize immersive learning environment. However, most of the existing studies have focused on a single dimension of instructor competency and they failed to interpret the comprehensive nature of instructors' competencies (Abdinejad et al., 2021; Gorman et al., 2022; Zhao & Zhang, 2021).

Therefore, through the implementation of empirical research, this study will comprehensively investigate university instructors' competencies suitable for VR, in order to provide targeted opinions for the cultivation of instructors' competencies in VR, and then improve the quality of China's higher education informatization reform.

2.4 Theoretical Foundations

Instructors' competencies are defined as an integrated set of personal characteristics, knowledge, skills, and attitudes that are needed for effective performance in various teaching contexts (Bos, 1998; Stoof et al., 2002). Instructors' competencies have been changing with the emergence of new teaching technology. At the same time, instructors' competencies reflect the professional development process of teachers. According to this, Teachers' Professional Development Theory and Technological Pedagogical Content Knowledge (TPACK) Theory are the theoretical basis for studying the information teaching competency of university instructors.

Teacher professional development refers to the dynamic and continuous development process in which teachers aim at professional growth and improve their professional philosophy and ethics, professional knowledge, and professional ability (Yu, 2015). From the 1960s to 1970s, the professionalism of the teaching profession was defined internationally, emphasizing that teachers are those who need continuous learning to maintain their expertise and skills. The theory of teacher professional development first began in 1969 when the American scholar Fuller mentioned in the Teacher Concerns Questionnaire, which indicated a path for teacher professional development. Fuller's "stages of concern theory" divided teacher professional development into four stages, namely, pre-teaching concerns, early concerns about survival, teaching situation concerns, and concerns about students (Yu, 2015). In China, the stages of teacher professional

development are generally categorized into four stages: pre-service, entry, in-service, and exit. Teacher professional development theory provides the theoretical background for this study to explore instructors' competencies and provide directions for the improvement strategy of instructors' competencies in a VR environment.

With the advance of the information age, American scholars Koehler and Mishra proposed the Technological Pedagogical Content Knowledge (TPACK) theory on the basis of Pedagogical Content Knowledge (PCK) in 2005. TPACK theory is considered by international scholars as a model for instructors' new knowledge structure in the information age. The elements of this theory include content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), which are components of technological integration. In the process of teaching, the three elements interact with each other inseparably and combine to form a new structure, which in turn helps instructors to use information technology to guide student learning. However, the combination of the three is not a simple addition, but an effective integration of information technology into the content and teaching methods. In other words, in this study, instructors' information technology competencies not only apply the original teaching ability to the technology teaching environment, but also integrate teaching competencies and information technology to reconstruct teaching competencies suitable for the technology teaching environment. A virtual reality environment is a teaching environment supported by VR. The integration of instructors' content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) constructs new instructors' competencies, which supports the innovation of this research.

3. Research Design

3.1 Research Participants

The participants of this study came from four selected medical universities in China. The selected universities have a wide range of students' sources and diverse majors, such as medical image technology, medical testing, pharmacy, clinical medicine, health services and management, and dental medicine. All the participants have been studying on the same virtual reality platform and they have been taught by the instructors trained for using the same virtual reality technology. The survey collected 660 questionnaires, excluding those with too many omitted items (more than 3) and those with regular responses. A total of 651 valid questionnaires were obtained, with an effective rate of 98.6%. Among them, 228 (35%) were medical image technology, 209 (32%) in medical testing, 62 (10%) in pharmacy, 124 (19%) from health services and management, 24 (4%) in clinical medicine, and only 4 from dental medicine. Most of them were female (N=476), with 175 males. Among these participants, 172 (26.4%) were less than 18 years old, 468 (71.9%) were 19–21 years old, and 11 (1.7%) were more than 22 years old. Among these participants, 159 came from cities (24.4%) while 492 came from the countryside (75.6%).

Table 1
The Basic Information of the Participants

Items	Categories	Numbers	Percentages (%)
Gender	Male	175	26.9
	Female	476	73.1
Age	18 years and below	172	26.4
	19-21 years old	468	71.9
	22 years old and above	11	1.7
Birthplace	Cities	159	24.4
	Countryside	492	75.6
Majors	Medical Image Technology	228	35
	Medical Testing	209	32
	Pharmacy	62	10
	Clinical Medicine	24	4
	Health Services & Management	124	19
	Dental Medicine	4	0.6

3.2 Research Procedures

The research procedures were mainly divided into three steps: (1) Based on the IBSTPI competency standards to determine the initial items of the instructors' competencies scale in virtual reality environment; (2) Through the pre-test to explore the reliability and validity of the scale, revise the questionnaire to form the final questionnaire; and (3) Carry out formal empirical research and data analysis. All participants studied in the same VR platform for 16 weeks. At the end of the semester, the participants evaluated their instructors' competencies from their perspective using the adapted questionnaire. Before administration, all the participants were informed about the purpose of the questionnaire and related confidential information. All of the research participants were asked to complete the questionnaires in the classroom.

3.3 Research Measures

The IBSTPI competency standards list in detail the instructors' competencies that instructors should possess in different information-based teaching environments, emphasizing the characteristics of instructors' competencies. The IBSTPI competency standards are applicable to the study of instructors' competencies in Chinese higher education because they have been proven to be global and full-stage versatility. This study is mainly based on the IBSTPI competency standards, drawing on the dimensions and specific topics in them, and the characteristics of the virtual reality learning platform to develop a questionnaire for instructors' competencies in VR environment. The IBSTPI competency standards include five dimensions of instructors' competencies: professional foundation, planning and preparation, instructional methods and

strategies, evaluation and implementation, and management, which are further divided into 18 specific competencies and 98 specific topics. Given that the respondents of this study were the students as the evaluators, the questionnaire was selected only with the instructors' competencies that the students could perceive. The final questionnaire contained two sections with basic information of participants and six dimensions of instructor competency scale which included establishing and maintaining learning motivation competencies, expressing competencies, questioning competencies, giving feedback competencies, promoting knowledge consolidation competencies, and facilitating knowledge transfer competencies. A total of 21 items was in the scale (as shown in Table 2). The scale was scored on a 5-point Likert scale, ranging from "not at all" to "completely," with higher scores representing stronger teaching competencies in the virtual reality environment.

Table 2

Number of Items in the Questionnaire

Parts	Dimensions	Numbers (pcs)
Basic Information	... ...	4
Instructors' Competencies in Virtual Reality Environment Scale	Establishing and maintaining learning motivation	5
	Expressing	3
	Questioning	4
	Giving Feedback	3
	Promoting knowledge consolidation	3
	Facilitating knowledge transfer	3

After the initial formation of the questionnaire, the reliability and validity of the scale needed to be tested. According to the test results, the final questionnaire was formed. The scale of instructors' competencies in virtual reality environment included six dimensions, with a total of 21 items. The reliability of this scale was analyzed by SPSS 21.0. The overall Cronbach α value of the instructors' competencies scale in VR environment was 0.994, which was greater than 0.8, indicating that the reliability of this scale was high. The Cronbach α values of the six dimensions of the scale all exceeded 0.8, indicating that the reliability of each dimension met the requirement.

The validity test of the scale was conducted using Smart PLS 3.0, and after the operation of PLS Algorithm, the loading coefficients of all items of the scale surpassed 0.7 and were significant ($p<0.05$); the composite reliability (CR) value should be greater than 0.7, and the higher the value, the better of the validity. The CR of the scale was above 0.8, indicating that the CR value of the scale reached the standard. The average variance extracted (AVE) should be higher than 0.5, which was used to measure the convergent validity of the scale, and all the items of scale were greater than 0.5, which meant that the scale was reasonably classified and had convergent validity; CR and AVE both

reached the standard value, which meant that the scale had appropriate construct validity (Joseph, 1998). Finally, the discriminant validity (DV) of each group was tested using the method proposed by Fornell and Larcker (1981). The result of validity test is shown in Table 3.

Table 3
Results of the Validity Test of the Scale

Variables	Indicators	Loadings	Composite Reliability(CR)	Average of variance extracted(AVE)
Establishing and maintaining learning motivation	1	0.966	0.984	0.926
	2	0.963		
	3	0.969		
	4	0.964		
	5	0.950		
Expressing	1	0.978	0.980	0.943
	2	0.965		
	3	0.970		
Questioning	1	0.965	0.976	0.910
	2	0.950		
	3	0.953		
	4	0.947		
Giving feedback	1	0.968	0.969	0.912
	2	0.951		
	3	0.946		
Promoting knowledge consolidation	1	0.942	0.971	0.919
	2	0.969		
	3	0.965		
Facilitating knowledge transfer	1	0.968	0.975	0.929

4. Empirical analysis of instructors' competencies in VR environment

4.1 General analysis of instructors' competencies in VR environment

The overall analysis and the six dimensions of instructors' competencies in virtual reality environment are listed in Table 4. It can be seen that the mean score of instructors' competencies was 3.86,

indicating the overall level of instructors' competencies was in the upper middle level, and still needed to be improved. The mean scores of instructors' competencies for the six dimensions were all over 3 points on a five-point scale, especially *facilitating knowledge transfer* and *questioning* (an average of 3.86 per dimension). Of the six dimensions of the instructors' competencies survey, *giving feedback* and *promoting knowledge consolidation* were in the middle level (an average of 3.85 per dimension), then both *establishing and maintaining learning motivation* and *expressing* attained 3.83. The result implied that most of instructors tended to show better ability to promote transfer of knowledge and show higher questioning competencies. Besides, they could provide effective and timely feedback to students and consolidate students' acquired knowledge in VR environment. However, *establishing and maintaining learning motivation* was deficient and university instructors lacked the competencies to express course content accurately and effectively in the virtual reality environment.

Table 4

The Current Status of Instructors' Competencies in VR Environment

	n	Maximum value	Minimum value	Mean value	Standard Deviation (SD)
Establishing and maintaining learning motivation	651	5	1	3.83	.769
Expressing	651	5	1	3.84	.774
Questioning	651	5	1	3.86	.751
Giving Feedback	651	5	1	3.85	.767
Promoting knowledge consolidation	651	5	1	3.85	.769
Facilitating knowledge transfer	651	5	1	3.86	.778
Instructors' Competencies	651	5	1	3.86	.763

4.2 Six-dimensional Analysis of Instructors' Competencies

The *dimension of establishing and maintaining learning motivation competencies* emphasizes a motivational tendency to stimulate and maintain learning behaviors and to orient learning activities toward learning goals, thus having a significant impact on learning outcomes. The mean value of 3.83 is the lowest among the six dimensions of instructors' competencies however. Among the five specific items in this dimension, they scored highest on "Instructors can use various teaching methods to attract and keep learning attention in the course" (an average of 3.85) and "Instructors can develop a good learning attitude" (an average of 3.85), followed by "Instructors can provide me with opportunities to participate in the course and succeed" (an average of 3.82), "Instructors can be able to provide me with clear and explicit learning objectives in the course" (an average of 3.81), and "Instructors can help me set reasonable expectations" (an average of 3.80). Clearly

instructors in VR environment were capable of using teaching methods and cultivating good attitudes toward learning to motivate learners and maintain them. Instructors were least able to help students set reasonable expectations.

The dimension of *expressing competencies* focuses on the competencies of instructors to express themselves effectively in the virtual reality environment. It had a mean score of 3.84, which was also at a low level among the six dimensions. The three specific items in this dimension were "Instructors can represent key concepts to me in a variety of ways in the course", "Instructors can provide me with examples to clarify the meaning in the course" and "Instructors can use appropriate expressions in the course according to the learning context" attained mean scores of 3.84, 3.84, and 3.83 respectively; there was not much difference between the scores of the three items. Relatively speaking, instructors were better able to effectively represent key course concepts to students using a variety of approaches and provide students with appropriate examples that clarify meaning in VR environment. However, they were less able to use appropriate expressions according to the learning context.

The dimension of *questioning competencies* stresses that instructors provide opportunities for students to participate in the learning process through effective questioning, and thus boost learning interest. It had a mean value of 3.86, which attained the highest scores among the six dimensions. The four items in this dimension scored, "Instructors are able to ask clear and appropriate questions" (M=3.85) and "Instructors are able to use questions to stimulate and guide discussion" (M=3.85), pursued by "Instructors are able to use a variety of question types and question levels in the course" (M=3.84) and "Instructors are able to follow up effectively on the questions I ask" (M=3.82). Results hint that instructors could reasonably grasp the timing of questions when teaching in VR environment, ask high-quality questions, set diverse types and levels of questions and facilitate students to think, but have poor mastery of questions pursuit and follow-up, which makes it difficult to promote students' in-depth learning of knowledge.

The dimension of *giving feedback competencies* examines whether instructors can provide appropriate feedback to enhance student performance and engagement in a VR environment. It had a mean score of 3.85, which was in a moderate level among the six dimensions. The three items in this dimension, "Instructors can use a variety of feedback strategies in their courses", "Instructors can provide me with clear, timely, pertinent, and specific feedback", and "Instructors can provide and receive feedback in a way that ensures openness and fairness" were not much of a difference, and scored 3.85, 3.84, and 3.84 respectively. This implied that the competencies of instructors for providing clear, timely, pertinent, and specific strategies for students and to ensure that the strategies were fair and open were lower than the competencies of using multiple feedback strategies, hence needed further enhancement.

The dimension of *promoting knowledge consolidation* reflects the competencies of instructors to facilitate the consolidation of students' knowledge in VR environment. It had a mean score of 3.85, which was also in the middle of the six dimensions. Among the three items in this dimension, "Instructors can provide me with opportunities to synthesize and integrate new knowledge" (M=3.86), followed by "Instructors can provide me with opportunities to link learning activities with existing knowledge" (M=3.84) and

"Instructors can provide me with opportunities to integrate new knowledge with existing knowledge"(M=3.84), the results indicated that instructors were better at consolidating students' knowledge by providing opportunities to synthesize and integrate knowledge. But there was a relative lack of ability to consolidate students' knowledge by providing opportunities to link learning activities to acquired knowledge and to provide opportunities for reflection and review.

The dimension of *facilitating knowledge transfer* attaches importance to show students how to apply acquired knowledge and provide opportunities for students to transfer knowledge. It had a mean score of 3.86, the highest of the six dimensions. There were three items in this dimension including "Instructors can provide me with opportunities to plan for future use" (an average of 3.87), which was higher than "Instructors can provide me with examples and activities related to knowledge and skills and the environment in which they are used" (an average of 3.85) and "Instructors can show me how to use knowledge and skills in real situations" (an average of 3.85). It suggested that instructors provided students with fewer cases and activities related to knowledge and application environments in VR environments. Results also showed that fewer demonstrated to students the use of knowledge in real situations, but provide relatively more opportunities for students to plan future applications.

5. Discussion, Conclusion and Further Studies

By adapting the IBSTPI competency standards, the study divided instructors' competencies into six dimensions. After the reliability and validity test, the "Instructors' Competencies in Virtual Reality Environment Scale" had been compiled and designed with good reliability and validity indicators.

In general, through the empirical research and questionnaire survey, this study found that the overall instructors' competencies in VR environment was in the upper middle level, and their ability of giving feedback, promoting knowledge consolidation, establishing and maintaining learning motivation, and expressing effectively were all lower than the mean value of the total instructors' competencies, meaning the development of each dimension was unbalanced. This conclusion is basically consistent with the findings of Guan's research that the overall level of wisdom learning ability of university teachers is at a medium level, but the development between different abilities is uneven, especially the ability to communicate in the virtual environment is poor (Guan, 2021). Teaching problems in the virtual reality environment such as untimely interactivity and lack of immersion need to be solved (Zhai et al., 2021). To optimize instructors' competencies in VR environment as a whole can start from two grips: the national level and institutional level. The country has a general leadership in the development of education and plays an important role in the cultivation and optimization of instructors' competencies in VR environment. At the national level, it can refine the relevant policy documents for teaching in the virtual reality environment and enrich the relevant policy paths according to the principles of difference and feasibility. Higher education plays an important role in societies to aid in an innovation diffusion (Marks & Thomas, 2022). As the organizer and implementer to improve instructors' competencies, universities can develop

VR training and educational framework to ensure quality content (Marks & Thomas, 2022). Universities can cultivate instructors' competencies in virtual reality environment through teacher education. Meanwhile, higher education institutions need to improve the entry threshold of instructors and refine the assessment and evaluation system of instructors in the virtual reality environment. This can further promote the integration of higher education and VR to achieve high-quality development of higher education, which in line with the opinion proposed by Gao and Wang (2016) to promote the deep integration between higher education teaching and VR.

Specifically, *questioning* and *facilitating knowledge transfer* dimensions had the highest mean scores among the six dimensions, indicating that instructors in the virtual reality environment also have the ability of effectively asking questions and transferring of knowledge to learners, consistent with Leong (2020) that VR-enabled learning can effectively expand the impact of the teaching and learning experience and facilitate knowledge transfer. Compared to the *questioning* and *facilitating knowledge transfer*, instructors still lacked in *establishing and maintaining learning motivation, expressing, giving feedback* and *promoting knowledge consolidation. Establishing and maintaining motivation* had the lowest score, followed by *expressing*, while *giving feedback* and *promoting knowledge consolidation* were at an intermediate level. The reason for the problems above may be that compared with the traditional teaching environment, VR environment presents richer and more diverse characteristics, which challenges the original instructors' competencies. This is also supported by the opinion that VR features brought new challenges for traditional teaching design (Zhang & Wu, 2019).

In terms of specific items, the items under *questioning* showed instructors in VR environment were lacking in following up skills on students' questions. Additionally, specific items under *expressing* indicated the VR environment had fewer opportunities to provide students with examples or practical applications related to teaching and learning than to plan future applications. The specific items of *establishing and maintaining motivation* showed that the failure of instructors to help students set reasonable expectations for the course and to set clear and explicit learning goals in the virtual reality environment was the key reason for the low ability to motivate and maintain students' learning. Specific items of *giving feedback* indicated instructors were able to use a variety of feedback strategies in courses in VR environments, but the clarity, timeliness, pertinence, openness, and fairness of the feedback strategies still needed further improvement. Xiang et al. (2021) experimentally confirmed that feedback in VR environment had a significant effect on learners' empathy; there was a significant mediating effect of empathy in the process of feedback for learning effectiveness. Therefore, instructors need to strengthen the construction of good feedback mechanisms in VR environment. Figols Pedrosa et al. (2023) proposed new instructional methods in VR teaching environment to help students consolidate their knowledge in a short term. Specific items of *promoting knowledge consolidation* showed that instructors were less able to provide students with opportunities to integrate acquired knowledge with practical activities and failed to give students sufficient chances for reflection and review, which could

affect the effectiveness of learning in a virtual environment. Those above analysis implied that university instructors still need to pay more attention to improve their competencies of *expressing, giving feedback, promoting knowledge consolidation,* and *maintaining learning motivation* in VR teaching environment.

In conclusion, the national level should refine relevant policies regarding teaching in VR environments and universities should provide training support for instructors. Most importantly, instructors as the main body of teaching in virtual reality environment should have full play of their own initiative in the decisive factor to improve their competencies in VR environment. Therefore, instructors must start from themselves, learn actively, plan scientifically, and reflect timely to strengthen their competencies in VR environment. Particularly, they should improve their competencies to motivate and maintain learning motivation in VR environment, effectively use various teaching methods to attract and keep students' attention, and then motivate and maintain students' learning motivation in the course, Further, instructors should enrich their teaching expressions in VR environment, and improve their ability to choose appropriate expressions according to the learning situation. At the same time, instructors should improve their ability to follow up on problems and optimize feedback strategies. They can follow up on students' questions and optimize feedback strategies, and focus on further improving the clarity, timeliness, pertinence, openness, and fairness of feedback strategies. Finally, instructors should also focus on learner' integration of theory and practice to promote the construction of the new "VR+ higher education" system.

This study explored at university instructors' competencies in virtual reality teaching environment from students' learning experience, while several limitations should be taken into account. First, the scope of this study is not comprehensive and the sample size is not wide enough. Therefore, the findings of this study need to be extended to other regions and majors for further research. Secondly, in addition to the six dimensions of instructors' competencies, other perspectives on instructors' competencies that influence student experience may exist, and thus, future research can further explore this aspect. Finally, the questionnaires for this study were collected based on a specific virtual reality platform. Future research could infuse instructors' competencies in virtual reality environment questionnaire into additional platforms.

References

Abdinejad, M., Ferrag, C., Qorbani, Hossain. S., & Dalili, S. (2021). Developing a simple and cost-effective markerless augmented reality tool for chemistry education. *Journal of Chemical Education, 98*(5), 1783–1788.

Bos, E.S. (1998). Competentie: verheldering van een begrip [*Competence: Clarifying a Concept*] (Otec Report 98/RO1). Heerlen: Open Universiteit Nederland (Onderwijstechnologisch expertisecentrum).

Chen, Y., & Xu, S. (2022). Cultivation method analysis for teachers' teaching ability driven by artificial intelligence technology. *Advances in Multimedia, 2022,* e5298291.

Dan, A., & Reiner, M. (2018). Reduced mental load in learning a motor visual task with virtual 3D method. *Journal of Computer Assisted Learning, 34*(1), 84–93.

De Carolis, B., D'Errico, F., Macchiarulo, N., & Palestra, G. (2019). Engaged faces: Measuring and monitoring student engagement from face and gaze behavior. *IEEE/WIC/ACM International Conference on Web Intelligence - Companion Volume,* 80–85.

Dionisio, J. D. N., Burns iii, W. G., & Gilbert, R. (2013). 3D Virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys, 45*(3), 34:1-34:38.

Distinguished teaching award. (2015, January 26). Retrieved May 4, 2023, from: http:// teaching. berkeley. edu/ distinguished -teaching -award

Du, S. (2021). Application analysis of virtual reality VR Technology in art design teaching. *Journal of Physics: Conference Series, 1881*(2), 022056.

Duo, Q., & Zhong, M. Y. (2017). TEP project by Oregon University and its inspiration on the university teachers' teaching capability in China. *Heilongjiang Researches on Higher Education,*(04), 121-125.

EDUCAUSE. (2022). 2022 *EDUCAUSE horizon report: Teaching and learning edition*. The EDUCAUSE website. Retrieved May 4, 2023, from: https://library.educause.edu/-/media/files/library/2022/4/2022hrteachinglearning.pdf?la=en&hash=6F6B51DFF485A06DF6BDA8F88A0894EF9938D50B.

Faculty guide to campus life. (2015, January 10). Retrieved May 4,2023, from: http:// faculty guide.berkeley.ehu/teaching/ menu_10.html

Figols Pedrosa, M., Barra Perez, A., Vidal-Alaball, J,. Miro-Catalina, Q,. Forcada & Arcarons, A. (2023). Use of virtual reality compared to the role-playing methodology in basic life support training: a two-arm pilot community-based randomised trial. *BMC Med Educ 23*, 50.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research (JMR), 18*(1), 39–50.

Gao, D. F., & Wang, S. (2016). The Influences and measures for the development of virtual reality technology on the Higher Education experimental teaching reform. *China Higher Education Research,* (10), 56-59.

Gorman, D., Hoermann, S., Lindeman, R. W., & Shahri, B. (2022). Using virtual reality to enhance food technology education. *International Journal of Technology & Design Education, 32*(3), 1659–1677.

Guan X. Y. (2021). *A study on the intelligent learning ability of teachers in western Universities - A case study of N university.* JiangSu: Nanjing Normal University.

Guasch, T., Alvarez, I., & Espasa, A. (2010). University teacher competencies in a virtual teaching/learning environment:

Analysis of a teacher training experience. *Teaching and Teacher Education: An International Journal of Research and Studies, 26*(2), 199–206.

Hair, J. F. (1998). *Multivariate data analysis (5th ed.).* New Jersey: Prentice Hall.

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education, 8*(1), 1–32.

Han, X. B., & Ge, W. S. (2018). Investigating the Chinese college teacher's competencies for ICT integrated into teaching: A survey study. *China Higher Education Research,* (07), 53-59.

Hu, W. P. (2021). Initial probe into assessment of teaching ability of teachers. *China Examinations,* (10), 12-17.

Hua, Z. X., Ouyang. Q., Zheng, K. F., & Cai, J. X. (2021). A Study on the construction and validation of a virtual reality technology teaching effectiveness model (VR-E3 Model). *Modern Distance Education Research*(02),43-52.

Huang, D. Q., Zhao, H., & Zhang, J. (2017). Feasibility analysis on the application of virtual reality for psychological quality education. *Advances in Education,* (04), 210-215.

Huo, J. F., & Yue, X. Z. (2021). Research and implementation of mechanical virtual experiment teaching platform. *The International Journal of Electrical Engineering & Education* (18).

Leong, W. K. (2020). Virtual Reality Empowers New Learning Exploration. *Preparing 21st century teachers for Teach Less, Learn More (TLLM) pedagogies. Kumar, Pradeep, (Ed); Keppell, Michael James, (Ed); Lim, Chee Leong, (Ed),* 243-258.

Lewis, P. H. (1994, September 25). He added 'virtual' to 'reality'. *New York Times,* 144(49830), 7.

Lopez, M., Arriaga, J. G. C., Nigenda Álvarez, J. P., González, R. T., Elizondo-Leal, J. A., Valdez-García, J. E., & Carrión, B. (2021). Virtual reality vs traditional education: Is there any advantage in human neuroanatomy teaching? *Computers & Electrical Engineering,* 93.

Makransky, G., & Lilleholt, L. (2018). A structural equation modeling investigation of the emotional value of immersive virtual reality in education. *Educational Technology Research & Development, 66*(5), 1141–1164.

Marks, B., & Thomas, J. (2022). Adoption of Virtual Reality Technology in Higher Education: An Evaluation of Five Teaching Semesters in a Purpose-Designed Laboratory. *Education and Information Technologies, 27*(1), 1287–1305.

Ministry of Education. (2021, June 9). Solidly promote the development of high-quality education and accelerate the construction of a strong education country. Retrieved March 4, 2023, from: http://www.gov.cn/xinwen/2022-10/25/content_5721685.htm.

Ministry of Industry and Information Technology, Ministry of Education, Ministry of Culture and Tourism General, Administration of Radio and Television General, Administration of Sports. (2022, October 28). Notice on the issuance of the Action Plan for the Integration of Virtual Reality and Industry Applications (2022-2026). https://www.gov.cn/. Retrieved May 4, 2023, from: http://www.gov.cn/zhengce/zhengceku/2022-11/01/content_5723273.htm.

Ning, X. B. (2021). Design of online popular music teaching platform based on embedded computer network and virtual reality. *Journal of Ambient Intelligence*

and Humanized Computing, (13),151.

Reen, F. J., Jump, O., McEvoy, G., McSharry, B. P., Morgan, J., Murphy, D., O'Leary, N., O'Mahony, B., Scallan, M., Walsh, C., & Supple, B. (2022). Developing student codesigned immersive virtual reality simulations for teaching of challenging concepts in molecular and cellular biology. *FEMS Microbiology Letters, 369*(1).

Selvi, K. (2010). Teachers' competencies. *Cultura, 7*(1), 167–175.

Shin, D.-H. (2017). The role of affordance in the experience of virtual reality learning: Technological and affective affordances in virtual reality. T*elematics and Informatics, 34*(8), 1826–1836.

Simpson, R. D., & Smith, K. S. (1993). Validating teaching competencies for graduate teaching assistants: A national study using the Delphi Method. *Innovative Higher Education, 18*(2), 133.

Stoof, A., Martens, R., van Merriënboer, J., & Bastiaens, T. (2002). The boundary approach of competence: A constructivist aid for understanding and using the concept of competence. *Human Resource Development Review, 1*, 345–365.

Sutherland, I. (1963). *Sketchpad: a man-machine graphical communication system.* PhD dissertation, Massachusetts: Massachusetts Institute of Technology.

Zhai, X. S., Sun, Y. L., Shen, Y., & Pan, J.J. (2021). Exploring the effect of "VR+Haptics" on improving learning efficiency: A Meta Analysis from 2010 to 2021. *Journal of Distance Education, (05),*24-33.

Zhang, F. J., & Wu, Q. (2019). Interactive Design for real-world mapping of virtual reality. *HCI International 2019* - Posters, 1033, 456-460.

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