# Tsing XiaoAI: A Digital Teacher in Virtual Environment

Jiahao Li[1], Wai Kin Victor Chan[2(✉)], and Ke Fang[2]

[1] Interactive Media Design and Technology Center, Tsinghua University, Beijing, China
lijiahao21@mails.tsinghua.edu.cn
[2] Shenzhen International Graduate School, Tsinghua University, Beijing, China
chanw@sz.tsinghua.edu.cn

**Abstract.** Digital humans have become a significant area of focus in the fields of computer graphics and human-computer interaction research. In this context, we propose a technical framework for the implementation of digital teachers in virtual teaching environments. To evaluate the effectiveness of our design concept and technical approach, we developed Tsing XiaoAI, a digital teacher, and conducted a randomized controlled trial (RCT) involving 90 primary school students. The RCT aimed to examine the impact of the digital teacher on students' subjective experience and objective learning outcomes. The technological validation results indicate that our proposed technical framework is a feasible solution for integrating digital teachers into virtual teaching environments. Furthermore, the experimental findings suggest that digital teachers have a positive effect on enhancing students' interest in learning, increasing virtual classroom interactivity, and significantly improving learning outcomes.

**Keywords:** Digital teacher · Virtual reality · Elementary education · Virtual teaching environment

## 1 Introduction

The concept of the Metaverse [1–3] and the advancements in computer graphics have led to a growing interest in digital humans as a research topic [4, 5]. As shown in Fig. 1, Digital humans are computer-generated virtual beings that typically resemble humans and can interact with humans in various ways [6]. There are two main types of digital humans: AI-driven and real human-driven [7]. AI-driven digital humans use artificial intelligence technology to generate expressions, voices, and actions, and they can sense and respond to their environment. Real human-driven digital humans are created by capturing and transferring the real-time movements, expressions, and other information of real humans, which is then rendered in real-time for presentation [8].

Interactivity is a crucial factor in determining the effectiveness of teaching [9], and teachers typically serve as organizers of classroom interaction. In the digital era, students are increasingly exposed to virtual digital content such as cartoons and video games. This trend has led to the emergence of virtual classrooms as a cutting-edge research area


F. Huang et al. (Eds.): ICAIE 2023, AHCS 15, pp. 182–190, 2024.
https://doi.org/10.2991/978-94-6463-242-2_22

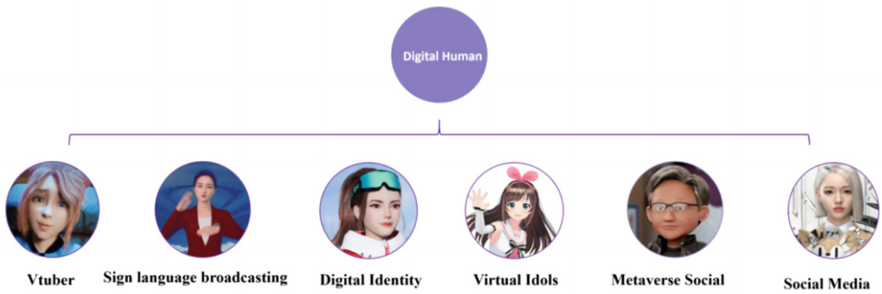


**Fig. 1.** Digital human

[10–12], with hardware facilities becoming more accessible. Virtual teaching environments offer significant potential for enhancing cognition, understanding, and memory, especially for elementary school students. Such environments enable the display of content that may be difficult or impossible to replicate in the real world and provide the opportunity to experience teaching content in a surreal way. With the advancement of information technology and the widespread availability of related hardware, the application of virtual teaching environments in actual teaching is becoming increasingly prevalent. Digital teachers have a clear advantage in teaching in virtual environments, serving as a bridge between the real classroom and the virtual environments.

## 2 Technical Framework

We propose a novel technical framework for digital teachers that utilizes 3D modeling, motion-capture technology, and real-time rendering, enabling real-time interaction between digital teachers and students. As shown in Fig. 2, our framework comprises four essential modules: the digital teacher module, motion-capture module, virtual environment module, and webcast module. In our framework, the digital teacher model is constructed using 3D modeling software, and motion-capture technology is employed to generate the expressions and movements of the digital teacher. The motion-capture data and multi-modal information of the digital teacher are transmitted to students through the network, allowing for real-time interaction.

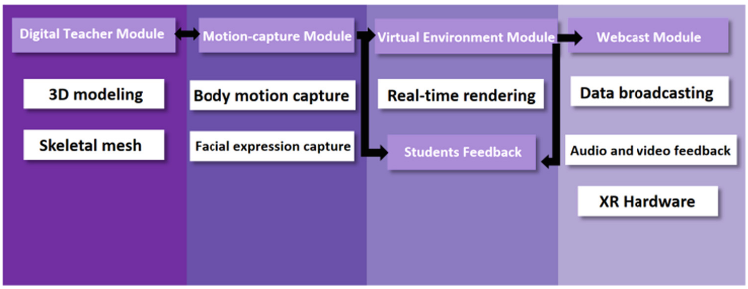


**Fig. 2.** Technical framework

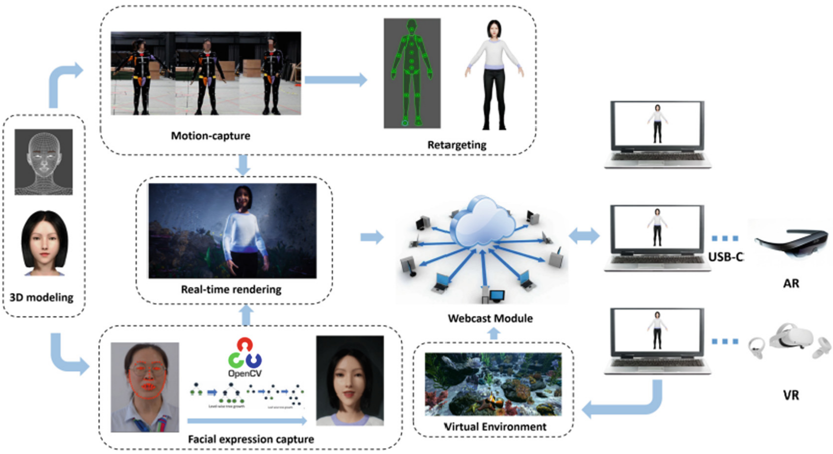


**Fig. 3.** Technical framework of Tsing XiaoAI

## 3 Digital Teacher Tsing XiaoAI

To assess the feasibility of our technical framework and evaluate the effectiveness of digital teachers in teaching, we developed a digital teacher named Tsing XiaoAI.

As shown in Fig. 3, to enable Tsing XiaoAI to operate effectively within virtual environments, we utilized real-time rendering with game engines, which allows for the rendering of dynamic virtual content and facilitates a variety of interactions. Additionally, given that many schools provide students with personal tablets, our webcast module enables digital teachers to distribute and display their lessons on each student's device, thereby increasing accessibility and convenience.

Considering the importance of experiential and field-based instruction in these classroom settings, we carefully selected course content that would require vibrant and immersive teaching modalities that are difficult to replicate using traditional pedagogical methods. To this end, we developed our virtual classroom, Deep Blue, as an optimized learning environment for ocean general education classes at the upper elementary level.

## 4 Experimental Research and Data Analysis

We conducted an experiment to investigate the teaching effectiveness of digital teachers, as shown in Fig. 4. The study primarily evaluated the effectiveness of digital teachers from two perspectives: 1) the subjective experience of students, which included an assessment of students' classroom immersion, participation, and interest; and 2) the objective evaluation of students' learning effectiveness by objectively evaluating students' knowledge mastery.

### 4.1 Questionnaire Design

To explore the effectiveness of virtual teaching, based on GEQ questionnaire, we designed a questionnaire to evaluate students' subjective experience (Table 1).

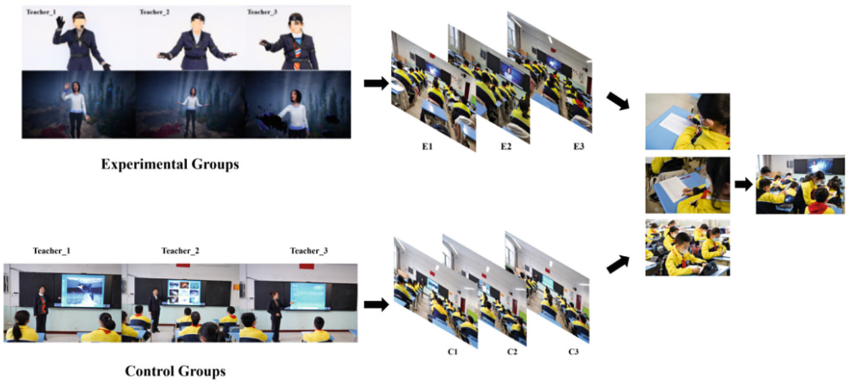


**Fig. 4.** Experimental process

**Table 1.** Questionnaire Design

| No. | | Dimension |
|---|---|---|
| Q1 | I think classroom interaction is fun. | Immersion |
| Q2 | I have a strong impression of this classroom interaction. | |
| Q3 | During class, I forget about everything else. | Flow |
| Q4 | I am fully engaged in the class. | |
| Q5 | I feel satisfied. | Positive affect |
| Q6 | I feel good. | |
| Q7 | I feel a sense of accomplishment. | Competence |
| Q8 | I am skillful. | |
| Q9 | I think classroom learning is challenging. | Challenge |
| Q10 | I have put in a lot of effort. | |
| Q11 | I feel bored. | Negative affect |
| Q12 | I feel tired. | |
| Q13 | I feel frustrated. | Frustration |
| Q14 | I feel annoyed. | |

## 4.2 Test for Learning Outcomes

The learning test used in our study was an objective evaluation of students' learning outcomes. The test consisted of eight closed-ended multiple-choice questions (LQ1–LQ7), with four options for each question. The questions focused on the marine biology course's teaching knowledge points, and the test result was represented by the accuracy rate (Table 2).

**Table 2.** Learning test

| No. | |
|---|---|
| LQ1 | Which species of turtle has the largest body size? |
| LQ2 | Which animal is a reptile? |
| LQ3 | What animal is a coelenterate? |
| LQ4 | How many known species of marine organisms are there? |
| LQ5 | What kind of organism does clownfish have a symbiotic relationship with? |
| LQ6 | What is the largest animal in the world? |
| LQ7 | Which kind of fish is faithful and loyal in love? |

### 4.3 Experimental Design

The participants in this study consisted of 90 sixth-grade elementary school students (aged 11–13 years, $N = 90$), randomly assigned to six groups using a random table method. The study included three control groups (C1, C2, C3) and three experimental groups (E1, E2, E3). The control groups received traditional classroom teaching, where teachers delivered content in a conventional format. In contrast, the experimental groups received digital teacher teaching, where teachers wore motion-capture equipment to drive Tsing XiaoAI and interact with students in real-time. The experiment followed the principle of replication, with three teachers (Teacher_1, Teacher_2, and Teacher_3) conducting the experiment.

### 4.4 Experimental Data and Analysis

The questionnaire results are shown in Fig. 5. The analysis of the questionnaire data is divided into three dimensions: Positive (Q1–Q8), Challenge (Q9–Q10), and Negative (Q11–Q14). The reliability coefficients of each dimension level (Cronbach's $\alpha > 0.7$) meet the reliability requirements of the questionnaire analysis. We also conducted a validity analysis of the questionnaire items and found that there was a correlation among the variables ($KMO > 0.6$), satisfying the requirements for factor analysis.

As shown in Fig. 6, the independent samples t-test results show that there is a significant difference between the control group and the experimental group in the positive dimension (Q1–Q8). Based on the analysis of the mean differences, it can be concluded that the subjective experience of the experimental group in the positive dimension (Q1–Q8) is significantly better than that of the control group. This conclusion is in line with the prerequisite for conducting in-depth research on subjective experiences of interactivity.

To further investigate the differences between the experimental group and the control group in the dimension of challenge (Q9–Q10) and negativity (Q11–Q14), non-parametric tests were conducted on these two dimensions, as shown in Fig. 7. The results of the Mann-Whitney non-parametric test ($p > 0.05$) analysis indicate that digital teachers did not produce any negative effects.

The total accuracy rate of the learning test questions was calculated and converted into a percentage score.

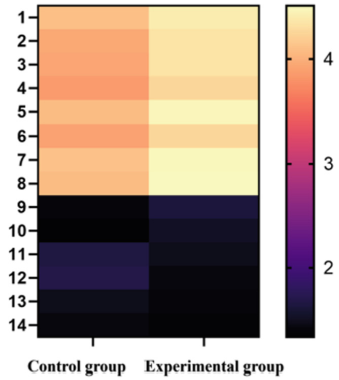


**Fig. 5.** The questionnaire results

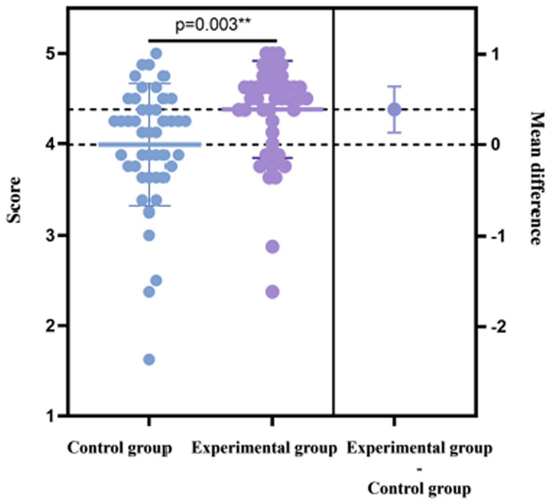


**Fig. 6.** t-test on the positive dimension (Q1–Q8)

As shown in Fig. 8, the Mann-Whitney test showed that there was a significant difference in learning outcomes between the experimental group and the control group ($p < 0.05$), with the experimental group outperforming the control group. This suggests that the introduction of the digital teacher enhanced the classroom's immersion, interactivity, and participation, thereby improving the overall learning outcomes of the experimental group.

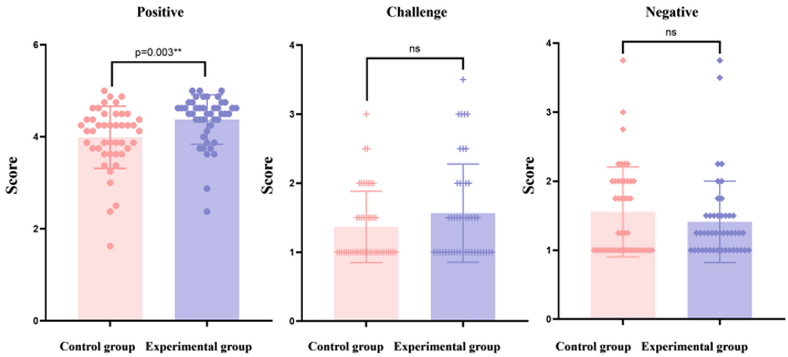


**Fig. 7.** Significant differences observed in the positive dimension, while no significant differences were found in challenge and negative dimensions

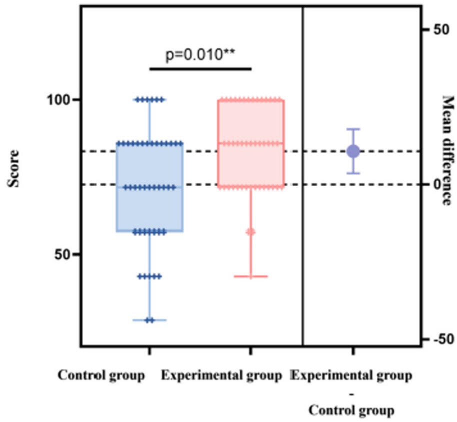


**Fig. 8.** Mann-Whitney test on the learning test (LQ1–LQ7)

## 5 Conclusion and Future Work

We propose a novel technical framework for digital teachers to teach in virtual environments and have demonstrated its efficacy through experiments. Our framework is designed based on state-of-the-art media technologies such as virtual reality, motion-capture, and real-time rendering. The digital teachers created using this framework offer enhanced teaching effectiveness and a superior learning experience for students.

Our study aimed to validate the efficacy of our proposed technical framework for digital teachers in virtual environments. To this end, we created a digital teacher named Tsing XiaoAI and developed Deep Blue, a virtual classroom for the upper elementary level. We evaluated the impact of digital teachers on students' subjective experience and learning outcomes. Our findings revealed that students in the digital teachers group outperformed their counterparts in the control group in terms of positive subjective experience and learning effectiveness.

In future work, we plan to further expand the scope of our technical framework by exploring its application in diverse virtual environments beyond Deep Blue. Additionally, we intend to investigate the application of our framework in other contexts beyond education, such as live streaming and concerts. Furthermore, we will explore the effects of digital teachers on individuals across different age groups to gain insight into the potential impact of digital teachers on learners of varying ages. Our goal is to continuously improve and expand the scope of our technical framework to enhance the effectiveness and applicability of digital teachers in various domains.

**Acknowledgements.** The authors would like to thank the anonymous reviewers for their valuable comments. This research was supported by Prototype Experiment of Educational Metaverse Based on Agent (20229680144), Shenzhen International Graduate School, Tsinghua University.

## References

1. Sparkes, Matthew. What is a metaverse. 18. (2021): https://doi.org/10.1016/S0262-4079(21)01450-0
2. Wang, Y., Su, Z., Zhang, N., Xing, R., Liu, D., Luan, T. H., & Shen, X. A survey on metaverse: Fundamentals, security, and privacy. IEEE Communications Surveys & Tutorials. (2022). https://doi.org/10.1109/COMST.2022.3202047
3. Lee, Lik-Hang, et al. All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda. arXiv preprint arXiv:2110.05352 (2021).
4. Dwivedi, Yogesh K., et al. Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management 66 (2022): 102542. https://doi.org/10.1016/j.ijinfomgt.2022.102542
5. Dionisio, John David N., William G. Burns III, and Richard Gilbert. 3D virtual worlds and the metaverse: Current status and future possibilities. ACM Computing Surveys (CSUR) 45.3: 1-38. (2013). https://doi.org/10.1145/2480741.2480751
6. Kang, Youna. CodeMiko: an interactive VTuber experience. SIGGRAPH Asia 2021 Re-al-Time Live!. 1-1. (2021). https://doi.org/10.1145/3478511.3491309
7. Bredikhina, Liudmila, et al. Avatar driven VR society trends in Japan. IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW). IEEE, (2020). https://doi.org/10.1109/VRW50115.2020.00103
8. Li, Jiahao, et al. Gulliver's Game: Multiviewer and Vtuber Extreme Asymmetric Game. 2022 IEEE Conference on Games (CoG). IEEE, (2022). https://doi.org/10.1109/CoG51982.2022.9893555
9. Gardner, Rod. Classroom interaction research: The state of the art. Research on language and social interaction 52.3: 212-226. (2019). https://doi.org/10.1080/08351813.2019.1631037
10. Ackers, Jim, and Frank Hardman. Classroom interaction in Kenyan primary schools. Compare: a journal of comparative and international education 31.2 245-261. (2001): https://doi.org/10.1080/03057920120053238
11. Harper, Kimberly C., Kuanchin Chen, and David C. Yen. Distance learning, virtual classrooms, and teaching pedagogy in the Internet environment. Technology in Society 26.4: 585-598. (2004). https://doi.org/10.1016/j.techsoc.2004.08.002

12. Davis, Niki, et al. Illustrating the “virtual” in virtual schooling: Challenges and strategies for creating real tools to prepare virtual teachers. The Internet and Higher Education 10.1 27-39. (2007): https://doi.org/10.1016/j.iheduc.2006.11.001