Research on Elementary School Students' Participatory Animated Pedagogical Agent Design in the Educational Metaverse Context

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Abstracts*

With the rapid development of virtual learning environments, animated pedagogical agents have emerged as a key component of the learning experience. Animated pedagogical agents not only guide students through the learning process using verbal and non-verbal cues but also activate social responses by presenting engaging social cues, thereby triggering deep cognitive processing during learning. Digital characters and virtual personas are gradually becoming the focus of the education field, providing learners with an interactive learning environment. With the continuous advancement of AR technology, digital characters and virtual personas have become valuable educational resources. Through realistic agent characters, learners achieve a high level of integration with the learning environment, creating a rich, face-to-face learning interaction. Supported by cutting-edge technology, this study utilized Metahuman and Unreal Engine 5 to successfully develop four pedagogical agents, each with unique teaching roles, appearances, and personality types. Throughout the research process, emphasis was placed on the active involvement of elementary school students. Through collaborative design with researchers, students actively participated in constructing the appearance of the pedagogical agent roles. This collaborative design not only aligns with the demands of the educational metaverse but also significantly enhances students' cognitive awareness of the pedagogical agent roles, meeting learners' expectations. In terms of design, cooperative inquiry techniques were employed as an effective method for co-designing among elementary school students. This not only increased the involvement of upper-grade elementary students in the agent design process but also provided a practical set of guidelines for future design projects. Therefore, this study not only offers valuable insights for the development of educational technology but also provides practical methods and tools for promoting student participation in the design process.

Keywords: Animated Pedagogical Agents; Teaching Roles; Participatory Design; AR Books

Introduction

With the widespread application of technology-mediated learning, animated pedagogical agents are emerging as essential innovative tools in modern education. These virtual characters, characterized by their lifelike features, significantly enhance learners' outcomes through multimedia learning environments that emphasize social interaction teaching strategies. They play a noteworthy role in education and training scenarios, effectively boosting learners' academic achievements by cleverly integrating social interaction strategies.

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The development of pedagogical agents has shown diverse trends, encompassing various roles such as simulated teachers, students, and teaching assistants, providing users with richer interactive experiences. As the concept of the metaverse evolves, there is an increasing demand for pedagogical agent roles and personas, especially in educational settings. However, there is a relative lack of empirical analysis and design application concerning the elements of pedagogical agent roles in the current literature. This study aims to address this gap by innovatively integrating realistic characters into animated pedagogical agents using virtual engines. Through participatory design and questionnaire research methods, the study seeks to explore elementary school students' preferences for pedagogical agent personality and role images. Additionally, the research aims to fill the research gap in the design of pedagogical agent roles in the educational field, particularly in the metaverse environment, offering an innovative perspective for the future development of pedagogical agents. The study's objectives include:

Addressing pedagogical agent design challenges in the educational metaverse learning environment, with a focus on designing pedagogical agents tailored to the needs of augmented reality (AR) learning environments, providing learning partners and expert images that better align with children's expectations.

Utilizing collaborative design methods throughout the research process, treating children as co-designers of pedagogical agents to better understand their viewpoints and needs, ensuring that the agent model fully meets children's educational requirements.

Investigating the impact of pedagogical agent appearance on peer and expert role types to ensure that the agent's appearance aligns with the role it plays.

Through detailed measurements of student preferences for different pedagogical agent images, the research aims to determine which pedagogical agent image best aligns with student expectations and verify whether there is a relationship between children's preferences and the similarity attraction to agent images. This comprehensive study aims to create pedagogical agents more closely tailored to student needs through child-participatory design methods in the educational metaverse learning environment, enhancing educational effectiveness and learning experiences.

Literature Review

1. Animated Pedagogical Agents in the Educational Metaverse

In the context of education, the virtual world (VW) is a Pandora's box (Riley & Stacy, 2008). Due to the persistent existence of non-contact infections caused by COVID-19, the metaverse, with its characteristics of allowing simultaneous non-contact interaction of multiple people, has rapidly become a safe space for communication and interaction with others, deeply integrating into students' lives. It has quickly spread across various fields. Therefore, it is essential to thoroughly understand students' needs to provide higher-quality education using technological resources to enhance classroom learning experiences (Wu, Yu, & Gu, 2020).

According to the "2020-2021 Metaverse Development Research Report" released by Tsinghua University's New Media Research Center in September 2021, 2020 was considered a critical point in the virtualization of human society, and 2021 was referred to as the "Metaverse Year" (Warner, 2022). With the development of digital technology and the flourishing research in global metaverse studies, the metaverse is considered the future trend in education, with tremendous potential (Hwang & Chien, 2022). The metaverse typically

integrates various emerging information technologies, such as VR/AR/MR, 5G, cloud computing, artificial intelligence, and digital twins, shaping the latest form of the next-generation Internet. The existence of the metaverse is often coupled with various new technologies (Kang, 2021), combining VR/AR/MR, 5G, cloud computing, artificial intelligence, digital twins, and other emerging information technologies into a cohesive whole. It will shape the latest form of the next-generation Internet, ushering in an era of a smart and decentralized Internet with a fusion of virtual and real, ubiquitous connectivity, and intelligent openness. Previous literature has rarely discussed education metaverse from a design perspective but has mostly focused on technologies related to the metaverse in education. However, the research model of education metaverse, besides the technological capabilities of the metaverse, will undergo a new transformation with digital virtual characters as key elements for learners to interact with the metaverse world. The development of animated pedagogical agents (APAs) based on virtual characters and roles in educational metaverse works can be seen as a feasible path for the education book industry to achieve value-added based on its core advantages.

Animated pedagogical agents are characters (human-like or others) with animated features (Johnson, Rickel, & Lester, 2000). They primarily serve as mediators between users and computers by providing various forms of assistance, guidance, and feedback. Animated pedagogical agents are considered one of the initial ways for humans to reach the metaverse, especially in multimedia learning environments. They play a role not only as companions in learning activities but also as teachers in knowledge transmission, guidance, and leading learners' learning processes. Studies on the use of animated pedagogical agents in multimedia instructional design have found that it has a positive impact on enhancing learners' learning motivation, attention, and learning outcomes (Baylor & Ryu, 2003; Moreno, Mayer, Spires, & Lester, 2001). Therefore, the application of animated pedagogical agents in multimedia learning is crucial for learners' learning experiences and outcomes, representing a logical extension of the development and customization of new learning interfaces.

With the advent of artificial intelligence, the relationship between people and technology in virtual learning environments is becoming more personalized. Personalized digital characters and virtual images are becoming the most valuable educational resources. Therefore, the development of pedagogical agents is quite diverse, including simulated teachers, students, teaching assistants, and learning companions in teaching applications (Baylor & Kim, 2005). The use of personified agents presented in multimedia has enriched interactions with users. To meet the needs of teaching, agents can be endowed with personality, emotions, and cognitive abilities (Baylor & Ryu, 2003). Through in-depth literature research on animated pedagogical agents in the educational metaverse, it is found that the types of educational roles of pedagogical agents may affect learning. However, current empirical research on the characteristics of pedagogical agent image types is mostly focused on adults, with scarce research on upper-grade elementary students. Additionally, research on the educational role image of animated pedagogical agents in the metaverse environment is still lacking.

Furthermore, with the expansion of the concept of the metaverse (3D virtual space reality of various social activities), learners' demand for the role image of pedagogical agents has increased. So far, due to the characteristics of real-time processing on the network, the realization of characters in virtual space is limited to providing optimized data in a simple form. In addition, realistic character creation requires high-level human, capital investment,

and high skills. However, due to the rapid development of hardware and software, various solutions have been introduced. This study is pioneering in creating realistic characters using virtual engines and integrating them into animated pedagogical agents. Through participatory design and exploratory questionnaires, the study investigates the preferences of upper-grade elementary students for the images of these agents.

In the research field of animated pedagogical agents, there is a lack of in-depth research on the cognition and preferences of upper-grade elementary students for agent role images in virtual environments. This study, based on animated pedagogical agents in the metaverse, contributes to supplementing the relevant research on the design of agent role images in the educational metaverse field. It is an innovative topic with significant meaning.

2. Participatory Design in Elementary School Students

Participatory Design is a design methodology that extensively involves user participation, aiming to stimulate users' enthusiasm and proactiveness, with a special emphasis on including individuals with disabilities, refugees, the elderly, and children in society. User-centered design focuses on product usability, while Participatory Design takes user involvement to a deeper level. Research indicates that in multimedia learning environments, teaching agent images that align with learners' preferences significantly capture their attention and have a positive impact. However, a one-size-fits-all approach to teaching agents may not effectively promote learning. This could be related to researchers providing agent images that fail to meet individualized learner needs and spark interest. Therefore, when designing and using teaching agents, learner preferences and needs must be thoroughly considered to achieve optimal teaching effectiveness.

Learners exhibit distinct individual differences in their preferences for teaching agent external features, such as gender, age, and race, which impact their perceptions and attitudes toward agents (Johnson, Didonato, & Reisslein, 2013). Therefore, in collaborative design, this study will measure upper-grade elementary students' preferences for two categories of teaching agent images to select the most popular ones. This will contribute to enhancing the acceptance and appeal of agent images, fully leveraging the potential advantages of teaching agents.

3. Role of Virtual Teaching Agent Images

The application of animated pedagogical agents (APAs) is widespread, and the visual appearance of agents is the most intuitive aspect for learners during the learning process. The visual appearance of teaching agents plays a crucial role in their communication success. Teaching agents' visual appearance should resemble human-like characters to better simulate the social environment and facilitate interaction with learners (Fang Hao, 2020).

In the realm of animated pedagogical agents, the two most frequently employed roles in multimedia learning environments are expert agents and peer agents (Baylor & Kim, 2005). Beyond the conventional role of teacher/expert virtual agents, various agent types, such as learning companions, have increasingly become integrated into electronic learning environments (Baylor & Kim, 2005).

3.1 Expert Agent Role

Expert agents play a crucial role as key assistants in learners' knowledge construction, significantly influencing the learning process. Impressions and expectations of learners regarding agents are often shaped by their visual and auditory features. Expectations and attributions of teachers or lecturers have been shown to significantly impact students' academic performance, with higher expectations often associated with better learning

outcomes. Expert agents not only provide cognitive support to learners but also meet learners' social and psychological expectations of professional teachers. By communicating in a formal, professional, and authoritative manner, expert agents showcase high-level competence, motivating learners to engage in the learning process positively. Baylor and Kim (2005) designed expert agents to resemble middle-aged professorial figures, emphasizing formality, professionalism, and guidance, creating a respectful and trustworthy academic learning environment.

3.2 Peer Agent Role

Baylor and Kim's (2005) study, based on social learning theory, utilized peer agents as instructional tools, emphasizing the impact of similarity between learners and agents on self-efficacy beliefs. Results indicated that when peer agents matched learners' ages, it significantly increased motivation and learning outcomes. Peer agents play a crucial role in simulating peer interactions, covering aspects of behavioral modeling and emotional influence. This mechanism of simulating social interaction facilitates cognitive restructuring and growth, particularly among same-age peers, promoting positive thought exchange and providing a free and open learning platform. In Baylor and Kim's (2005) study, the peer agent was designed to resemble a male college student in his twenties, featuring casual clothing, expressive body language, enthusiastic voice, and expressions to facilitate social connections with learners. This social engagement not only signifies active interaction but also allows the agent to experience and reflect learners' emotional states, including frustration, annoyance, boredom, and joy. Similar peer agent models have been adopted in other studies, aiming to match the peer agent with participants and enhance overall learning experiences.

Study Participants

This study selected upper-grade elementary students as participants due to their demonstrated cognitive development, allowing for robust validation of the impact of teaching agents on learning outcomes. Students from three schools—Shijiazhuang Experimental Primary School, Renmin Road Primary School, and Xinyuan Primary School—were recruited from grades four to six. In the recruitment process, after obtaining consent from schools and parents, the voluntary nature of participation was emphasized. A "Participant Consent Form" was distributed to potential participants' parents to ensure that all participating students volunteered with the agreement of both parents and students. To further safeguard participants' rights, detailed experimental information was provided, including the purpose, process, risks, and benefits. The commitment to protecting participants' privacy was emphasized, and it was explicitly stated that participants could withdraw from the study at any time. This transparency and the established protective measures contribute to ensuring the ethical compliance of the research and participants' safety.

The study ultimately gathered 20 students as research subjects. The experiment was conducted in a quiet classroom of the elementary school. To alleviate participants' nervousness, communication and coordination with auxiliary personnel were conducted before the experiment. According to the research design, these participants were randomly assigned to two experimental groups, namely the expert group and the peer group, each consisting of 10 students. This grouping aimed to ensure that the samples in both experimental groups were representative and comparable in terms of age, gender, and other factors.

Participant eligibility was rigorously screened to ensure the credibility of the study. This included age between 9 and 12 years old, a balanced male-to-female ratio, normal intelligence, normal corrected visual acuity in both eyes, no color blindness or color weakness, absence of astigmatism, and right-hand dominance. These screening criteria help eliminate interference from other factors on the experimental results, providing a better understanding and analysis of the factors influencing the study.

Research Design

The experiment aims to develop a teaching agent that aligns with children's expectations in an AR book learning environment. Through participatory design methods, children are involved in the design process to ensure that the final agent model meets their expectations and cognition. During the design process, different external features are manipulated to verify whether peer and expert roles of teaching agents can be effectively identified. The purpose of this step is to ensure that the appearance of teaching agents aligns with their roles, better meeting children's educational needs. Specifically, during the model construction process, the study focuses on measuring upper-grade elementary students' preferences for two different images of teaching agents. This helps the research team select expert and peer images that best match student expectations, optimizing the design of teaching agents. Through in-depth analysis of the collected data, the study aims to verify whether children's preferences are related to the attractiveness of teaching agent visual features. Overall, the study's goal is to create more child-friendly teaching agents through participatory design methods, validate the effectiveness of appearance features, and understand children's preferences, ultimately finding the most suitable agent images to enhance educational outcomes and learning experiences.

Construction of Teaching Role Appearances

1. Design Concepts for Teaching Role Images

Recent research has highlighted the positive impact of teaching agents on societal presence, agent roles, and learning outcomes in terms of appearance and behavior (Davis et al., 2021). This finding underscores the importance of appearance in virtual educational environments. Clothing, as part of appearance design, plays a crucial role in teacher images (Baylor, 2011). Particularly, expert agents, by presenting the image of a formal, authoritative, and professional forty-year-old professor wearing formal shirts (Liew & Tan, 2021), convey a formal and professional image. This image selection is closely related to the formality of the environment, as wearing formal clothing leads to higher evaluations of teacher competence and professionalism. On the other hand, peer agents, as animated teaching agents, are based on the image of a casually dressed young student. Through appearance, features, empathy, positive influence, and social interaction, these agents enhance learners' motivation. This design aims to portray appearances and features more similar to learners, creating a friendly and empowering learning environment. The choice of appearance is crucial for shaping specific images in different teaching settings. In professional settings, expert agents dressed in formal shirts help convey formality and authority. In contrast, in non-professional environments, such as hoodies or T-shirts, a more natural and relaxed atmosphere is better suited (Flemban, 2018). This study also expresses the teaching roles and personality traits of virtual teaching agents through physical features, verbal features, and behavioral features. The selection of different images aims to evoke stereotypical impression features in perceivers,

thereby influencing expectations of the agents. The study emphasizes that the design of teaching roles and personality traits for agents should be customized based on user needs and goals to enhance learning effectiveness and user satisfaction. While there is currently a research gap regarding which appearance features are most effective for expressing specific personality traits, the research team plans to use new research tools to fill this gap and explore the correlation between the appearance features of teaching agents and personality traits.

1.2 Elementary School Collaborative Design of Teaching Role Images

Most agents are designed by adults, and we need more research on the types of teaching methods according to the actual needs of elementary school students. In this study, the process of constructing teaching agent models adopts participatory design by elementary school students. Participatory Design involves a wide range of interactions and coordination, unlike past design approaches. Participatory schemes require a process based on communication and coordination. Unlike previous studies, the model construction in this paper combines a novel virtual engine modeling system. The goal is to use participatory design by elementary school students to create teaching agents that meet the expectations and cognition of elementary school students and have distinct teaching role images.

Users and Research

Twenty elementary school students (aged 9-12) participated in the design of teaching agent role faces because appearance and behavioral features are essential factors in constructing animated teaching agent teaching roles and personality traits. With an increasing demand for virtual characters in the metaverse context, the virtual character creation software "Metauman Creator" developed by Epic Games provides an intuitive interface, detailed diversity, and physically realistic expressions based on actual scanning data. For example, users can adjust skin texture, hairstyle, clothing color and style, eye and mouth shapes, etc. (Figure 2). These details make digital characters more realistic and authentic, providing significant convenience to creators of animated teaching agents and greatly reducing development costs.

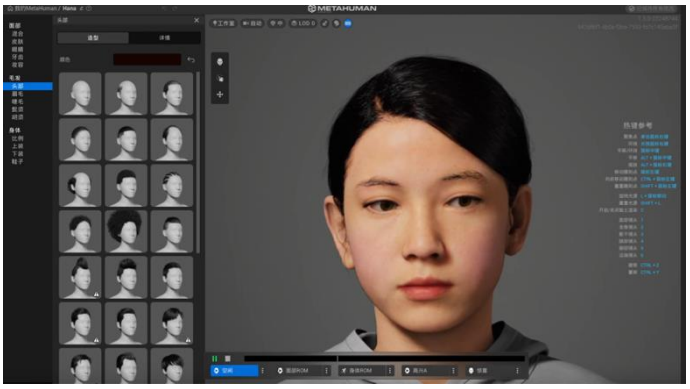

Figure 2: MetaHuman Creator Demonstration

Synthesizing Three-Dimensional Faces that Meet Requirements

Based on the design concept, users are required to synthesize three-dimensional faces that meet the specified criteria using the MetaHuman Creator, following the outlined procedure:

a. The experiment employs the MetaHuman Creator, and under the guidance of the researcher, participants synthesize three-dimensional faces that align with the research objectives. Initially, the researcher provides detailed information to the participants about the research goals and the essential features of the virtual teaching agent characters, showcasing the fundamental attributes of the MetaHuman model. Using images, videos, and other means, participants gain an understanding of the basic operations of the MetaHuman tool, such as adjusting hair, eyes, skin, and clothing.

b. Considering that participants may not be familiar with the MetaHuman tool, a 10-minute familiarization period is provided at the beginning of the experiment. Subsequently, the researcher provides descriptions of the appearances of companion and expert characters, instructing participants to construct two characters based on these descriptions. With the assistance of the researcher, participants select the initial characters and adjust parameters until they match their stereotypical impressions of an expert or companion figure. The researcher is responsible for offering guidance to ensure quality and allows for questions or breaks at any time.

c. Throughout the collaborative creation process of the model by students and the researcher, the researcher collects model data, including names, appearances, attributes, etc., for subsequent analysis. The entire experiment aims to investigate the process and outcomes of participants creating teaching agent characters in the MetaHuman environment that align with expectations.

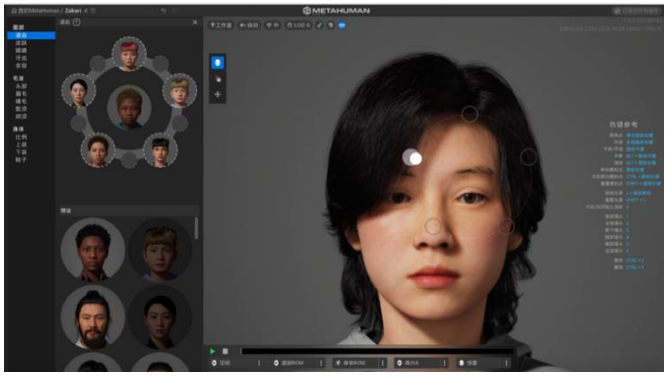

Figure 3: MetaHuman Creator Interface

1.3 Subjective Preferences of Elementary School Students for Agent Teaching Role Models

Materials and Methods:

A questionnaire experiment was conducted with 280 elementary school students to investigate their perceptions and preferences for four types of teaching agent role models. Visual images of each agent's appearance were presented using questionnaire materials containing static images of 40 frontal views, with 20 images for each category (peer and expert teaching roles). The images were standardized in terms of external conditions, such as brightness.

The selection criteria for the materials were based on the ability to reflect typical visual images of characters representing teaching roles. The questionnaire materials, determined through expert review, aimed to assess participants' perceptions of teaching role types, preferences for agent roles, and descriptive adjective scales related to visual attractiveness. Participants rated each image on a five-point Likert scale for preference and recognition of teaching role types, resulting in a total of 40 questions. Questions 1-20 assessed participants' preference levels for teaching role images, while questions 21-40 evaluated participants' recognition levels of expert/peer teaching role types. The entire questionnaire took approximately 15 to 20 minutes to complete.

Results

The study involved an in-depth evaluation of 20 different teaching agent role images by participants, focusing on role preferences and recognition. The results were analyzed comprehensively, providing average values and standard deviations for each teaching agent role image to better understand participants' perceptions and preferences for these roles.

Specifically, role preference indicated the degree of participants' liking for the characters in the visual stimuli. Role recognition referred to participants' perception of the expert and peer teaching role types in the stimulus materials. These metrics offered crucial information about participants' emotional and cognitive responses to different role images.

Group statistical analysis using SPSS revealed that older elementary school students exhibited a stronger preference for peer roles among the 20 teaching agent role images. When comparing the mean preference values, peer role images had a significantly higher mean than expert role images. Specifically, the mean for expert role images was 3.73, while the mean for peer role images was 4.23, highlighting participants' inclination to choose agent teaching role images similar to themselves, i.e., peer images. There was a significant difference in recognizing expert and peer identities among elementary school students ($p < 0.05$). Further observation of mean values indicated that peer images ($M = 3.94$, $SD = 0.88$) were significantly higher than expert images ($M = 3.38$, $SD = 1.05$), demonstrating a significant ability to recognize images. Therefore, the construction of both expert and peer images was considered to align significantly with the cognitive abilities of elementary school students.

This trend was evident in the group statistical results of role preference, providing researchers with valuable insights into the psychological inclinations of older elementary school students toward different teaching agent role models. This insight is crucial for designing more appealing and student-expectation-aligned teaching agent images, ultimately aiming to enhance educational effectiveness and learning experiences.

Table 1: Descriptive Statistics of Role Preference

Role Preference Group = Expert	Mean[value]	Standard Deviation	Role Preference Group = Expert	Mean[value]	Standard Deviation
Character Image 6	3.73	1.180	Character Image 14	4.23	0.892
Character Image 1	3.71	1.036	Character Image 13	4.06	0.830
Character Image 7	3.71	1.073	Character Image 18	4.05	0.835
Character Image 3	3.69	1.099	Character Image 11	4.00	0.905
Character Image 2	3.66	1.037	Character Image 12	3.90	0.812
Character Image 8	3.63	1.049	Character Image 20	3.88	0.823
Character Image 5	3.63	0.922	Character Image 16	3.88	1.057
Character Image 10	3.55	1.041	Character Image 15	3.87	0.975
Character Image 4	3.48	1.210	Character Image 17	3.87	0.983
Character Image 9	3.38	1.177	Character Image 19	3.86	1.070

Data Source: Compiled by this study

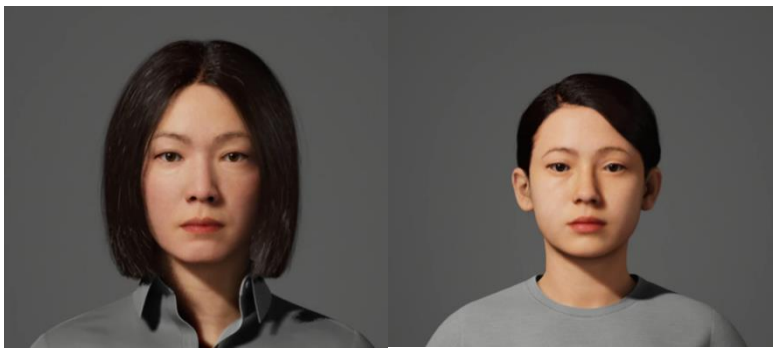

Figure 4: Teaching agent roles most preferred by elementary school students

Table 2: Independent sample t-test for recognition accuracy

Recognition Group		N	Mean[value]	Standard Deviation	T	p
Role Recognition	Expert	128	3.38	1.05	-4.626	0.000
	Peer	128	3.94	0.88		

Data Source: Compiled by this study

In this study, a meticulous examination of the analysis results of the assessors revealed a significant recognition ability among older elementary school students when assessing the appearance features of two types of collaborative design agent teaching roles: experts and peers. This indicates that participants were able to effectively distinguish between these two teaching role images, allowing for the construction of appearance features more aligned with children's cognitive perceptions.

Further exploration into the theory of similarity attraction involved the use of univariate analysis of variance (ANOVA) to assess whether the means between different groups were influenced by the attraction of similarity. The analysis results presented a significant level in the test of between-subjects effects ($p < 0.05$), indicating a substantial main effect. Moreover, the main effect of role recognition groups on role preference also exhibited significance ($p < 0.05$), implying that participants' recognition of peer images significantly influenced their preference for peer images. However, the interaction term "role recognition group * role preference group" did not significantly affect role preference, suggesting that the ability to recognize teaching role types did not directly influence participants' preferences for teaching role images.

This series of analytical findings provides profound insights into understanding participants' cognitive perceptions and preferences for different teaching roles, guiding the design of more appealing and expectation-aligned teaching agent images for children.

Table 3 Inter-Subject Effects Test

Dependent variable:

Source	III Category Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Adjusted Model	21.413a	3	7.138	11.211	0.000
Intercept	2127.778	1	2127.778	3342.222	0.000
Role Recognition Group	13.560	1	13.560	21.299	0.000
Role Preference Group	0.123	1	0.123	0.194	0.660
Interaction between Role Recognition Group and Role Preference Group	0.359	1	0.359	0.564	0.454
Error	160.432	252	0.637		
Total	3855.720	256			
Corrected Total	181.845	255			

R-squared (R^2) = .118 (adjusted R^2 = .107)
Data Source: Compiled by this study.
The above findings indicate that, when participants choose agents, they prioritize the similarity in role recognition rather than the similarity in role preference.

To determine the suitability of the scale for practical measurements and assess the contribution of each item to the overall scale, this study conducted reliability and validity analyses on the scale. The results of the reliability analysis indicate that the validity of these two variables is high, making them suitable for use in related research. Factor analysis using the maximum variance method (with an extraction condition of eigenvalues greater than 1) was employed to assess the structural validity of the scale, as shown in Table 4, demonstrating good structural validity.

Table 4 Reliability Analysis:

Variables	Clone Bach Alpha	Number of items
Character image preference	0.948	10
role identification	0.956	10

Data Source: Compiled by this study

Table 5
Validity and exploratory factor analysis:

KMO Sampling suitability quantity.		0.930
Bartlett's sphericity test	Approximate chi square	4440.791
	degree of freedom	190
	Significance	0.000*

Data Source: Compiled by this study

Research Findings,The research results indicate that the construction of visual characteristics for educational agent roles has gained recognition and affirmation from students. The images of both types of agents meet the expectations and perceptions of students. The role recognition group significantly influences role preference, suggesting a tendency for individuals to interact with those who have similar role recognition. However, further investigation is needed to determine whether this similarity affects students' learning outcomes.

Conclusion

To construct educational agent roles and personality types that align with the preferences and perceptions of elementary school students, two experiments were conducted in collaboration with participants. Innovative research tools and methods were employed to establish facial and personality features for different educational roles. The Metahuman model creation tool was used, and students collaborated in the creation process, exploring stereotypes associated with peer and expert educational roles. Through surveys and manipulation tests, the study identified the most fitting peer and expert images for elementary school students

and determined the key design points for expert and peer images.

In the manipulation experiment, participants demonstrated the ability to distinguish between educational role types based on visual features and perceive the personality information expressed by the agents through language and non-verbal behaviors. This indicates the success of the study in designing and manipulating educational role types and personality traits, validating the effectiveness of similarity attraction at both the visual and personality levels. Collaborative design with elementary school students proves to be a highly promising research area, harnessing their imaginative ideas and creativity with researcher guidance through experiments like Metahuman. Furthermore, the study provides an effective method for constructing and testing different educational role types and personality traits in agents, showcasing innovative work. Importantly, the manipulation test results suggest that these manipulations align with the study's objectives. Future research is encouraged to further utilize the model to investigate the impact of educational role types and personality traits on learning outcomes.

Recommendations for Future Research

This study aimed to provide an innovative scientific approach for designing educational agent roles that align with the preferences and perceptions of upper-grade elementary school students through in-depth exploration of participatory design, surveys, and objective measurement methods. The preliminary exploration of visual cognitive processes in upper-grade elementary students within the educational metaverse focused on understanding the impact of different educational agent roles on student preferences and cognitive responses.

In proposing future research directions and recommendations, several key areas were highlighted by the researchers:

1.Exploration of the impact of different educational contexts: Researchers are recommended to investigate the influence of various educational settings, including traditional classrooms, online learning, and personalized learning. Interdisciplinary research, integrating knowledge from educational psychology, cognitive neuroscience, and educational technology, is considered crucial to provide a more comprehensive perspective.

2.Emphasis on personalized learning technology: Future researchers can focus on developing personalized learning systems that offer tailored materials and feedback based on students' personality traits and educational role types.

3.Longitudinal tracking studies: Researchers are encouraged to conduct long-term tracking studies to understand whether the learning outcomes associated with different personalities and educational agent types change over time. This type of study will contribute to a more comprehensive understanding of students' growth trajectories, revealing changes and trends in the learning process.

By addressing these limitations and embracing future recommendations, researchers can continually refine study designs and methods, providing robust support for the further development of the field. These forward-looking directions and recommendations will guide future researchers in better understanding the multifaceted influences on learning outcomes.

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