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Building Participatory Teaching Agents and Teaching Roles for Elementary Students in the Metaverse Context

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Abstract

In the virtual learning environment, human-computer interaction interfaces are being imbued with more human-like characteristics, such as virtual teaching agents. These agents can utilize voice, gestures, facial expressions, and other cues to guide student learning. The presence of such agents in the learning process bridges the gap between human-computer interaction and real-life human-human interaction, activating social interaction patterns and facilitating deeper cognitive processing for learning. With advancements in metaverse technology, personalized digital characters and virtual avatars have become valuable educational resources. Realistic agent roles integrate learners and the learning environment, creating rich face-to-face learning interactions.

In this technological context, we developed four teaching agents using a novel and emerging social technology system called Metahuman combined with Unreal Engine 5. These agents, as realistic virtual digital humans, were incorporated into the learning experiences of elementary students, with two different types of teaching roles and appearances, as well as two different personality types. In this study, we involved elementary students in the design and evaluation of the virtual teaching agents' personality and role representations, aiming to develop animated teaching agents that meet both the requirements of educational metaverse and learner expectations. The results indicate that involving elementary students in the co-design process with researchers enhanced their understanding of the personality and role representations of the teaching agents. Using collaborative inquiry as an appropriate method for co-designing with elementary students improved their participation in the design process of the teaching agent roles. This study provides a set of guidelines for the participatory process, which can be applied to future design projects to support project teams in determining the process and tools for involving elementary students.

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Keywords: Virtual teaching agents, Personality, Teaching roles, Participatory design.

1. Introduction

With the increasing popularity of Technology-Mediated Learning (TML), animated characters or agents are being used as interfaces between humans and machines to facilitate human-machine interaction. Animated Pedagogical Agents (APAs) refer to intelligent or motivational virtual characters used in educational or training settings. These agents possess lifelike animation characteristics and employ various teaching strategies emphasizing social interaction in multimedia learning environments. They have been found to have a strong positive impact on learner outcomes and are regarded as attractive roles. Consequently, the development of teaching agents has become diverse, including simulated teachers, students, assistants, and learning companions. The use of multimedia presentations with humanoid appearances enriches interactions with users. To meet educational needs, agents can be endowed with personality, emotions, and cognitive abilities.

With the expansion of the metaverse concept (a three-dimensional virtual space for various social activities), the demand for teaching agent roles in educational avatars has also increased.

Through an in-depth review of literature on animated pedagogical agents in educational metaverses, it is evident that both the personality and teaching role of teaching agents can influence learning outcomes. However, due to the limitations of real-time processing in virtual spaces, the implementation of roles in virtual environments is restricted to simplified forms with optimized data. This research is innovative in creating realistic characters through a virtual engine and integrating them into animated pedagogical agents. It explores the preferences of elementary school students for teaching agent personality and teaching role through participatory design and questionnaire-based investigations.

Furthermore, there is currently limited empirical analysis and design application of teaching agent roles combined with personality design elements. This study contributes to the research on the combination of teaching agent roles and personality design in educational metaverses, providing innovative insights into the topic.

This article makes the following contributions:

Based on the preferences and perceptions of elementary school students regarding ideal characteristics of teaching agents, a model is constructed for teaching agent roles (expert/companion) and agent

personality (extroverted/introverted) using participatory design and innovative research tools combined with questionnaire surveys.

2. Literature Review

2.1 The role of the character image of virtual pedagogical agents in education

In multimedia learning environments, the visual appearance of an agent is the most immediate perception for learners during the learning process. The image elements of pedagogical agents form our initial impressions of them and influence the way we interact with them. Therefore, the visual image of a pedagogical agent should resemble human-like characters to better simulate the social environment and facilitate learner-agent interaction (Fang, 2020; Shumanov & Johnson, 2021). In the context of animated pedagogical agents, two commonly used roles are expert agents and peer agents in multimedia learning environments (Zhan, 2011). The expert agent role refers to an intelligent entity that possesses expert-like characteristics in its appearance. By presenting a high expectation and task value, expert modeling enhances learners' learning potential (Belland, Kim, & Hannafin, 2013). This expert modeling provides highly effective strategies for problem-solving. By implementing expert-like agents in the system, learners tend to attribute higher confidence and trust to their instructions. On the other hand, peer agents simulate the interaction of peers during the learning process. Following Bandura's (1997) social modeling concept, Baylor and Kim (2005) operationalized this agent as similar to the learner. When learners see peer agents who are similar to themselves, "the similarity of attributes between learners and social models significantly influences learners' self-efficacy beliefs." Thus, when peer agents are of the same age as the learners, motivation and learning will be enhanced.

2.2 The personality of virtual pedagogical agents

In daily life, people automatically judge others' stereotypical personality traits based on visible characteristics (Borkenau & Liebler, 1992). Personality is an important social feature of animated pedagogical agents, and according to the media equation hypothesis (Reeves & Nass, 1996), users observe significant cues through the design and behavior of pedagogical agents, and their judgments of animated pedagogical agents are similar to judgments of humans.

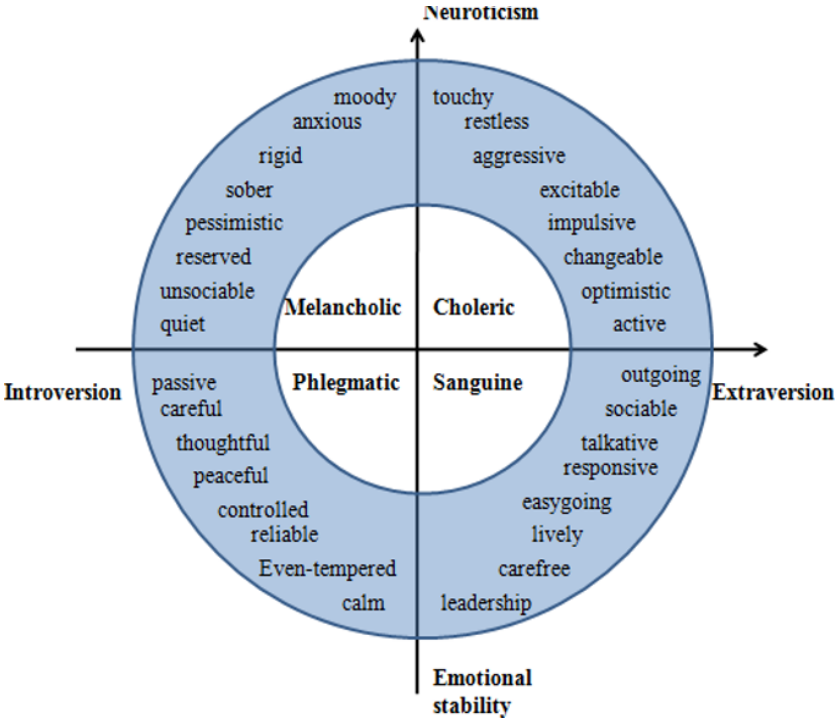
Existing research suggests that the development of agent personality can draw on psychological knowledge (Mcrorie, Sneddon, Mckeown, Bevacqua, Sevin, & P, 2012). Animated pedagogical agents can exhibit their personality through specific visual appearance, behavioral characteristics, and linguistic cues. For example, the appearance of the pedagogical agent is an effective cue for personality judgment. Dress

style, such as formal attire, is an indicator of conscientiousness (Borkenau & Liebler, 1992). Behavioral characteristics, such as facial expressions, gestures, and movement amplitude and speed, also serve as important cues for personality judgment. Speech features are another common way to express personality (Thomas, Ferstl, McDonnell, & Ennis, 2022). Researchers have created interfaces that successfully display personality traits using both verbal and non-verbal cues, and users have responded to these interfaces with social behaviors (Nass & Moon, 2000). The aforementioned research demonstrates that many factors of appearance can influence accurate personality judgments, but in the current study, we focus only on facial features and speech behavior as personality cues.

2.3 The theoretical basis for constructing agent personality types

The design of teaching agents' personality requires reliable personality theories to achieve high psychological validity (McRorie et al., 2012). From existing research, most work in affective computing relies on psychological models, and researchers primarily lean towards two personality theory models: the Big Five personality traits and the Eysenck Personality Model. The Big Five personality traits are a commonly used classification of personality traits (Barrick & Mount, 1991). Although many researchers use the Big Five model to explore and design the personality of teaching agents and support the effectiveness of this model in personality design (Dekker, 2012), it is challenging to accurately design based on the five dimensions provided by the model. In contrast, Eysenck established a trait-based model, suggesting that virtual agents require parameters that are easy to control (Arya, Jefferies, Enns, & DiPaola, 2006). Eysenck's model allows for the categorization of personality into different types, enabling the generation of virtual characters with different personality types. In Eysenck's model, four different personality types (melancholic, choleric, phlegmatic, and sanguine) are produced by combining two different quadrants of the superordinate factors of extraversion and neuroticism (see Figure 1), and the four primary dimensions that meet these criteria are extraversion, introversion, neuroticism, and psychoticism.

Figure 1: Eysenck Theory Model



Based on the aforementioned reasons, this study will rely on Eysenck's theoretical model to design the personality of the animated teaching agent. According to the media equation hypothesis, people's judgment of animated teaching agents follows the same principles as their judgment of humans. Therefore, mapping human extraversion-introversion language features into corresponding non-verbal and verbal behaviors of animated teaching agents becomes possible. Among the two main dimensions of extraversion and neuroticism in Eysenck's theoretical model, current research has focused on extraversion for three reasons: firstly, extraversion (i.e., extraversion-introversion) plays an important role in our interactions with non-human subjects (Dryer, 1999). Secondly, extensive research has shown that extraversion is most pronounced in humans and has the highest level of consistency among observers (Kenny, Horner, Kashy, & Chu, 1992). Finally, this dimension has been proven to be important in human-computer interaction (HCI) (Isbister & Nass, 2000; Moon & Nass, 1996; Nass & Lee, 2001), and it is reasonable to assume that it will continue to be important in multimedia learning environments. According to the media equation hypothesis, people's judgment of animated teaching agents follows the same principles as their judgment of humans. Therefore, the mapping of human extraversion language features into corresponding non-verbal and verbal behaviors of animated teaching agents becomes possible. Thus, this research

explores the study of multimedia personality focusing on extraversion (Bian Yulong, 2016; Dryer, 1999; Isbister & Nass, 2000; Tapus & Mataric, 2008).

3. Shaping the image and personality of teaching agents

3.1 Construction of teaching role appearance

3.1.1 Design ideas for teaching role image

Recent research on teaching agents, peers, and instructors has shown that appearance and behavior can positively influence social presence (Parmar, Olafsson, Utami, & Bickmore, 2018), agent roles (Davis, Wan, Vincent, & Lee, 2021), and learning outcomes (Schneider et al., 2022). Furthermore, the appearance and behavior of experts, peers, or agents are associated with the roles of social entities. From the perspective of appearance design, considering the image of teachers in the classroom and media education environments, clothing may be crucial. Based on stereotypes, an expert-type agent can be portrayed as a professor in their forties, wearing formal attire (Liu, Chen, & Tu, 2017), and speaking in a formal, authoritative, and professional manner. The role of an animated teaching agent with a peer image is to promote learners' motivation and attitudes by having a similar appearance, characteristics, empathetic relationship, positive impact on self-efficacy, and social interaction. This can be achieved by portraying the agent as a young student wearing a hoodie or a T-shirt (Beege, Krieglstein, & Arnold, 2022), who speaks in a friendly yet authoritative manner (Baylor & Kim, 2005).

3.1.2 Collaborative design of teaching character images with elementary school students

Most proxies are designed by adults, and we need more research on the types of teaching methods that meet the actual needs of elementary school students. In this study, the process of constructing a teaching agent model involves participatory design with elementary school students. Participatory design encompasses a wide range of activities and differs from previous design approaches. It requires the design process to be based on communication and coordination. Unlike previous studies, this paper combines a novel virtual engine modeling system in the model construction, aiming to create teaching agents that align with the expectations and cognition of elementary school students through participatory design involving elementary school students, without teaching character images.

Users and Research

40 elementary school students (aged 9-12) participated in the design of teaching agent character faces, as both appearance and behavioral

traits are important factors in constructing animated teaching agent characters and personality features. With the increasing demand for virtual characters in the metaverse, a virtual character creation software called "MetaHuman Creator," developed by Epic Games, offers an intuitive interface, detailed diversity, and realistic expressions based on actual scan data. For example, users can adjust skin texture, hairstyle, clothing color and style, eye and mouth shape, and more (Figure 2). These details make digital characters more realistic and authentic, providing great convenience for animated teaching agent creators and significantly reducing development costs.

Figure 2: Demo of MetaHuman Creator

Synthesizing three-dimensional faces that meet the requirements

Based on the design concept, users are required to use Metahuman Creator with the assistance of researchers to synthesize three-dimensional faces that meet the requirements. The procedure is as follows:

a. Prior to the start of the experiment, researchers open the Metahuman Creator interface and provide participants with a detailed introduction to the purpose and specific content of the study. Participants are shown images and videos demonstrating the virtual characters of the teaching agents that need to be created for the study. Basic attributes and features of the Metahuman models, such as different types of characters, hair, skin, and clothing, are also presented. Participants are familiarized with the basic operation methods and steps of the Metahuman tool through demonstrations or hands-on practice, including how to adjust the appearance attributes of the models, such as hair, eyes, skin, and clothing. To ensure that participants can use the Metahuman tool correctly and complete the experiment smoothly, considering their unfamiliarity with the basic model adjustment functions of the tool, participants are given 10 minutes to familiarize themselves with the specific adjustable options in the Metahuman tool.

b. Participants are informed of the experimental task: Based on the identified characteristics of the teaching agent role appearance from the literature, researchers provide participants with a text description of both the peer image and the expert image. According to the literature, the expert image is described as an Asian woman in her 40s wearing a formal shirt, while the peer image is described as an Asian girl around 12 years old wearing a hoodie. After providing detailed analysis and clarification of the agent's appearance characteristics to the participants, each participant, with the assistance of the researcher, is required to construct two characters based on the characteristics of either an expert or a peer image, depending on their assigned group. Participants are instructed to collaboratively create the appearances of the two characters with the researcher, ensuring that they match their ideal expert/peer faces.

c. Participants select an initial character from the predefined template characters that best matches their expectations for the role. After selecting the initial face, participants, with the assistance of the researcher, adjust the customizable parameters of the character based on the chosen initial face. They continue to adjust the parameters until they achieve a face that conforms to their stereotypical impression of an expert or peer image (as shown in Figure 3). Researchers provide guidance and assistance to participants, guiding them in adjusting each parameter of the model to ensure successful completion of the model creation while maintaining quality. Participants are encouraged to ask questions or take breaks as needed.

Figure 3: The working interface of Metahuman Creator

d. During the collaborative process of students and researchers creating the models, the researchers collected the data of the completed character models, including the name, appearance, attributes, and other information. This data was recorded and would be used for further analysis.

3.1.3 Subjective preferences of primary school students towards agent teaching role models

Materials and Methods

A questionnaire survey was conducted with 280 elementary school students. Four teaching agent roles' visual appearances were determined from the perspective of elementary school students. Questionnaire materials consisted of images that displayed the appearance of each agent. The visual models of peer and expert teaching agent roles were decided upon through expert evaluation. A total of 40 static frontal images of agents were used, with 20 images for each category. The external conditions of these materials, such as brightness, were kept consistent. The main criteria for material selection were the ability to reflect typical visual appearances of teaching agent roles. The static images of each agent were edited to ensure standardized presentation to the students. Adobe Photoshop software was used to edit the teaching agent images, removing confounding variables such as background color, size, pixelation, and coordinate axes in the images and videos. The images were edited to provide a neutral outfit and background color. All images were also resized to ensure that differences in size would not affect the perception of different images by elementary school students. The questionnaire materials used in this study were decided upon after expert evaluation. During the evaluation of teaching agent types, participants observed the appearance images of 20 agents and rated the agents' appearances and their perceived teaching agent types and preferences. The perceived level of teaching agent types and subjective satisfaction were measured using a five-point Likert scale, with a total of 40 questions. Questions 1-20 assessed the participants' preference for the teaching agent appearances ("Based on the images you have seen, choose your preference for the following appearances"), with scores ranging from 1 (dislike) to 5 (like) to indicate the participants' visual preferences for the agent roles. Questions 21-40 required participants to rate their recognition of the teaching agent types ("Based on the images you have seen, choose your recognition level for the following appearances"), with scores ranging from 1 (cannot recognize at all) to 5 (can recognize well), to determine whether they could recognize the peer/expert teaching agent types for each agent. The rating scale ranged from low to high, with the lowest rating on the left and the highest rating on the right. It took approximately 15 to 20 minutes for elementary school students to complete each questionnaire.

The questionnaire design included four dimensions: perception of teaching agent types, preference for agent roles, evaluation of attractiveness using adjective scales, and basic demographic information. The data collected from the survey respondents'

perception and preference for animated teaching agents were further analyzed using SPSS software.

Results

The evaluators rated their preferences and recognition for the visual appearances of 20 teaching agent role models. These evaluations were aggregated to calculate the mean and standard deviation for each teaching agent role model. Role preference refers to the degree of visual preference that participants selected for the role models after processing the visual stimuli. Role recognition refers to the degree of recognition of expert/peer teaching agent roles in the stimuli after processing the visual stimuli. Using SPSS software, the preference ratings were statistically analyzed. As shown in Table 1, the role model preferred the most by elementary school students among the expert roles was number 6, and among the peer roles was number 14. In terms of the mean preference ratings, the mean for peer roles was higher than the mean for expert roles. The highest mean values for each group were: Expert Role Model Mean = 3.73, Peer Role Model Mean = 4.23. From the group statistics of role preference, it can be observed that the participants tended to prefer teaching agent role models that were similar to themselves, which were the peer roles.

Regarding the recognition of teaching agent role types by the evaluators, the analysis results are shown in Table 2. During the construction process of teaching agent role appearances, elementary school students and researchers cooperatively designed two types of teaching agent roles: expert and peer. There was a significant difference in the recognition of expert and peer identities by the elementary school students ($p < 0.05$). Upon further observation of the means, it can be seen that peer ($M = 3.94$, $SD = 0.88$) was significantly higher than expert ($M = 3.38$, $SD = 1.05$), indicating a significant recognition of the role models. Therefore, both the expert and peer role models were considered to be recognized by elementary school students in accordance with their cognitive abilities.

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

According to the similarity-attraction theory, we know that people tend to be more attracted to those who are similar to themselves because this similarity can increase emotional connection and generate attraction. From the analysis results, it can be observed that the differences in the role recognition groups significantly influence role preference. However, the interaction between role recognition groups and role preference groups does not have a significant effect on role preference. This means that the role preference groups do not

have an impact on role preference, so we only need to focus on the influence of role recognition groups on role preference.

Table 3 Inter-Subject Effects Test

Dependent variable:

Source	III Category Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Adjusted Model	21.413[a]	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 make choices regarding proxies, they prioritize similarity in role recognition rather than similarity in role preference.

To determine the suitability of the scale for practical applications and assess the contribution of each item to the overall scale, this study conducted reliability and validity analyses. The results of the reliability analysis show that both variables demonstrate high validity and can be used in related research. The factor analysis was performed using the maximum variance method (with an extraction criterion of

eigenvalues greater than 1), as shown in Table 4, indicating good structural validity of the scale.

Table 4: Analysis of Inter-Subject Effects

Dependent variable

Source	III Category Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
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Total	3855.720	256			
Corrected Total	181.845	255			

R-squared (R^2) = .118 (adjusted R^2 = .107)

Data Source: Compiled by the present study.

The research findings indicate that the construction of visual characteristics for teaching agent roles has gained recognition and affirmation from students. The images of both types of agents align with students' expectations and perceptions. The role identification group significantly influences the degree of role preference, suggesting that individuals are more inclined to interact with those who share similar identification. However, whether this similarity affects students' learning outcomes requires further investigation.

In the upcoming experiments, the two highest-rated images selected from each type of teaching agent role will be used to delve deeper into the construction of teaching agent personality traits.

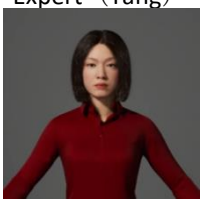
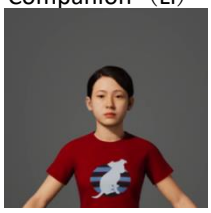
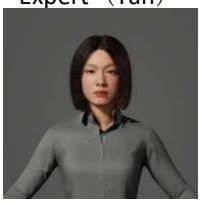
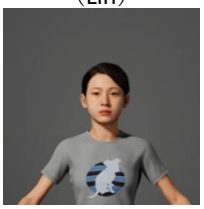
3.2 Personality trait construction

3.2.1 Design of personality parameters

Based on the Eysenck personality model, two sets of virtual teaching agents with different personality types were created. Based on the expert and peer models obtained from pre-experiment 1, we generated an extraverted expert (Yang) and peer (Li), as well as an introverted expert (Yan) and peer (Lin). These two types can be manipulated and defined based on Eysenck's factor combinations and measured using his parameters.

The personality types of the agents can be demonstrated by changing their appearance, behavior, and language characteristics. These characteristics are associated with stereotypical impressions of specific personalities and teaching agent roles (Devine, 1989). They are imprinted in the mind in the form of images and guide people's expectations of others' personalities in real time. Based on previous research findings, we associated the agent's appearance, language, and non-verbal behavior characteristics with the agent and their personalities (see Table 5).

Table 5 presents the personality parameters of the four agents

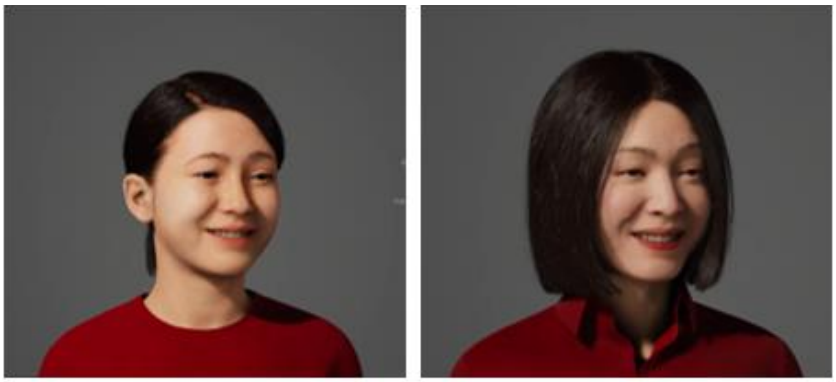
Agent Characteristics	Extroverted		Introverted	
Agent Type	Expert （Yang） 	Companion （Li） 	Expert （Yan） 	Companion （Lin） 
Facial Expressions	Smile		No expression	
Clothing Color	Red color		Gray color	
Volume of Voice	Larger/bigger		Smaller	
Speaking Rate	Faster		Slower	
Pitch of Voice	Higher/taller		Lower/shorter	
Body Movements	Movements expressed through arms, body, and head		Movements expressed through arms	

Gestures	Wider and faster	Slow and narrow gestures

Defining the facial features of virtual teaching agents

The facial features of the extraverted personality expert Yang and companion Li are defined as optimistic (Eysenck & Eysenck, 1985). Their facial expressions are set to a permanent optimistic expression, as they need to frequently exhibit behaviors of happiness and joy.

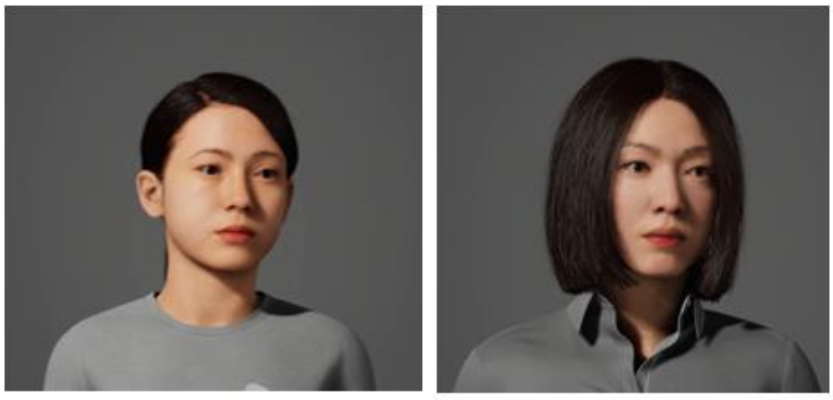
Figure 5: Facial Expression Features of Extraverted Personality Agents



Li Yang

The introverted personality experts, Yan and Lin, are defined as passive, calm, restrained, cautious, even-tempered, and composed (Eysenck & Eysenck, 1985). They have a neutral facial expression without any obvious emotions. They are depicted wearing low-saturation, symbolizing calmness and restraint, gray-colored clothing (Plass, Homer, MacNamara, Ober, Rose, Pawar, & Olsen, 2020) (as shown in Figure 6).

Figure 6: Facial Expression Features of Introverted Personality Agents



Lin Yan

Defining the behavioral characteristics of animated teaching agents

Behavioral characteristics are also an important aspect of expressing personality traits (Borkenau, Mauer, Riemann, Spinath, & Angleitner, 2004; Sonlu, Güdükbay, & Durupinar, 2021). Yang and Li have extraverted personalities. Research suggests that extraverted individuals tend to exhibit more bodily movements and higher levels of facial activity (La France, Heisel, & Beatty, 2004). Extraversion is also associated with higher levels of gestures and more frequent head movements (Borkenau et al., 2004). Taking these factors into consideration, we defined their behavioral characteristics in terms of two dimensions: movement speed and movement range. Finally, the facial activity, gestures, and actions of expert Yang and peer Li were defined as having higher speed and a larger movement range (as shown in Figure 7).

Figure 7: Behavioral Characteristics of Extraverted Personality in the Agents

In comparison, the facial movements, gestures, and actions of expert Yan and peer Lin are defined as having lower speed and smaller range of motion (as shown in Figure 8).

Figure 8: Behavioral Characteristics of Introverted Personality in the Agents

Defining the voice of the animated teaching agent.

Considering the association between extraversion and a loud, powerful voice (Borkenau et al., 2004), Expert Yang and Peer Li were given voices that align with their personalities (McRorie et al., 2012). Additionally, considering the link between emotional stability and a calm speaking style (Borkenau et al., 2004), Expert Yan and Peer Lin were assigned gentle voices with a calm tone and a composed speaking manner that matches their temperament (Borkenau & Liebler, 1992). In addition to voice tone, this study also differentiated their language expression, with extraverted personalities using more direct language while introverted personalities using more cautious and polite language (Borkenau et al., 2004).

3.2.2 The evaluation of primary school students towards the types of agent personalities

To successfully implement these designs, this study utilized the motion capture feature of the metahuman software in combination with the peer and expert images obtained from pre-experiment 1. Based on the summary of personality traits in the relevant literature regarding linguistic and nonverbal behavioral features, different actions were created in the Unreal Engine.

Although two agent personality types were generated based on scientific feature parameters, further testing is needed to determine whether these features can truly express the intended personality types. A total of 28 primary school students, aged between 7 and 13 years, completed the evaluation of the animation teaching agent's personality features at a primary school in China.

Materials and Methods

To facilitate the assessment of each agent's personality by perceivers, two sets of materials were created for the questionnaire, displaying the appearance, behavior, and language features of each agent. This included the selection of video clips depicting language and nonverbal behaviors related to extraversion personality, as well as the selection of static color images based on the facial appearance of the characters. The selection of images and videos, consisting of 12 static images (3 for each category) and 8 videos (2 for each category), was decided after review by relevant experts. The static images included frontal and approximately three-quarter left profile views of each teaching agent. The two videos included facial expression videos of each character and self-introduction videos of each teaching agent. For example, the companion Lin said, "Hello, I am Lin, and now I will be your learning partner," accompanied by certain body movements. The external conditions of these materials, such as brightness, were kept the same.

During the evaluation of the effectiveness of personality design, evaluators watched the videos of the four teaching agents and used the Extraversion subscale (consisting of 12 items) from the Eysenck Personality Questionnaire Revised-Abbreviated (EPQR-A) to assess their personality traits (Francis, Brown, & Philipchalk, 1992). The EPQR-A is a forced-choice questionnaire where each item requires a "yes" or "no" response. It is not used to measure specific behaviors but rather general behaviors associated with desired personality traits. Participants were asked to answer the 12 questions for each agent to evaluate statements such as "Do you think this statement applies to describing Expert Yang?" Students were required to evaluate all 12 questions for each teaching agent. We used the EPQR-A because of its simplicity and established reliability and validity as a measure of Eysenck's two-factor model (McCrae & Costa, 1987).

Results

The differences in personality traits and attractiveness among the four agents were examined using Analysis of Variance (ANOVA) and post hoc LSD tests. The analysis revealed significant differences among the four agents in terms of personality dimensions ($p<0.05$), as summarized in Table 10. Specifically, in terms of extraversion, the scores for the peers were significantly higher than those for the experts. However, there was no significant difference in scores between the experts and peers in terms of introversion.

These results indicate that the perceivers' judgments of the agents' personality types align with the design expectations. Furthermore, the manipulation test results further confirm the validity of the similarity attraction theory. This suggests that individuals are more likely to be attracted to and establish connections with people who are similar to themselves in social interactions. Additionally, the results of the one-way ANOVA showed no significant differences in attractiveness scores among the four images ($p>0.05$).

Overall, the results indicate that the control of personality parameters in this study was effective.

Table 10: Comparison of Personality Trait Scores

Total Personality Score	N	Mean[value]	Standard Deviation	F	Significance	LSD post-hoc test
Li	28	7.68	1.31	62.739	0.000	Li>Yang>Yan,Lin
Lin	28	4.50	0.84			
Yang	28	6.86	0.89			
Yan	28	4.57	1.20			

Data source: Compiled by this study

Table 11: Mean score comparison of the interaction between agent features and agent types

Agent Features	Extroverted		Introverted	
Agent Types	Expert（Yang）	Companion（Li）	Expert（Yan）	Companion (Lin)
Mean Score	6.86	7.68	4.57	4.50

Source: Compiled by this study

Table 12: Analysis of Agent's Appearance Attractiveness

Agent Name	Mean[value]	Standard Deviation	F	Significance
Li	3.54	1.232		
Lin	3.29	1.512	0.628	0.598
Yang	3.11	1.397		
Yan	3.11	1.257		

Data source: Compiled by this study

4. Discussion

To construct teaching roles and personality types for animated teaching agents that align with the preferences and cognition of elementary school students, two experiments were conducted in this study. Both experiments involved collaboration with participants to create teaching agents with different teaching roles and personality types.

In the experiments, an innovative research tool and methodology were used to establish facial features and personality traits for different teaching roles. Experiment 1 employed the highly user-friendly Metahuman modeling tool and collaborated with elementary school students to comprehensively investigate the stereotypical impressions associated with the appearance features of the two teaching roles: peer and expert teaching agents. Through questionnaires and manipulation tests, this study identified the peer and expert images that best met the expectations of elementary school students and determined the key design points for the appearance features of the expert and peer agents.

Subsequently, Experiment 2, based on Eysenck's personality classification model, combined Eysenck's personality descriptions with previous research findings to create agents with two personality types: introverted and extraverted. To express the agents' personality traits, it was necessary for perceivers to link external features of the agents to relevant stereotypical impressions of personality and make

corresponding inferences about their personality traits. This study created two sets of actions to express extraversion and introversion, coordinated with voice, to better convey personality information.

Through manipulation experiments, this study found that perceivers were able to distinguish the teaching roles of the teaching agents based on their appearance features and perceive their expressed personality information through their language and nonverbal behavioral features. This indicates that the design and manipulation of teaching roles and personality traits for the teaching agents in this study were successful, and it also demonstrates the effectiveness of similarity attraction at the level of appearance and personality. Collaborating with elementary school students proved to be a highly promising research area. Due to their imaginative and creative nature, elementary school students can engage in creative activities with the assistance of researchers, which can lead to the development of innovative approaches. The use of Metahuman in this study enabled close collaboration with elementary school students during the research innovation process. Furthermore, this study provides an effective method for constructing and examining different teaching roles and personality traits for agents, which is innovative in itself. Importantly, the results of the manipulation tests suggest that the manipulation of teaching roles and personality traits for the teaching agents aligns with the objectives of this study. We encourage future research to further explore the impact of teaching roles and personality traits of teaching agents on learning outcomes using the developed model.

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