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Investigating the impact of safety, cultural and character traits issues in the adoption of humanized robots in education

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The recent integration of humanized robots in education has a transformative potential, but identifying and addressing education and human-centric challenges is necessary for their adoption. This research investigates the relationships of safety issues, cultural issues and character traits concerns the humanized-robots with the adoption in learning environments. The theoretical foundation of the study is based on the Human-Robot Interaction Theory, Social Cognitive Theory and Diffusion of Innovation Theory, which provide insights and understanding regarding the relationships among variables for the adoption of humanized robots in education. The research employs quantitative methodology, where the data was collected through questionnaire surveys from 620 respondents in Pakistan and China and analyzed through Partial Least Squares Structural Equation Modelling. The results reveal that safety issues, character traits and cultural issues have significant relationships with the adoption of humanized-robots in educational settings. The findings offer novel understandings regarding the complex relationships of character, safety and cultural dimensions with humanized-robots adoption unlike the previous studies that focused on usefulness, ease of use, feasibility, outcomes etc. The study integrates the above-mentioned theories in a single framework and extends the understandings regarding technology adoption by incorporating safety, character traits and culture. Furthermore, it also underscores the significance and need of safety, positive character traits and cultural sensitivities for the development and broader acceptance of such technologies. The results provide valuable insights for developers, policymakers and educational institutions for designing culturally adaptive humanized robots, ensuring safety and extensive character traits training for reducing adoption challenges.

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Introduction

The current century is witnessing a significant momentum in the advancement of technologies (Coyle and Hampton 2024). One of the technological sectors that has gained substantial growth is robotics. During the previous decade, its advanced version, humanized robots started to be integrated into numerous sectors (Tong, Liu, and Zhang 2024). The education sector is also one of the potential sectors for the adoption of these humanized robots and some universities have started using these robots for teaching with the aim to improve learning experience (Schiavo et al. 2024). They are designed to show human like behavior when interacting with humans to make a more interactive and engaging learning environment (X. Wang et al. 2024). As these robots are using advanced technologies like artificial intelligence etc., they possess the capabilities to answer questions easily and provide students an enhanced personalized support (Barrera Castro et al. 2024). Although, having promising capabilities, their adoption in educational organizations faces some challenges that need a comprehensive investigation (Phillips et al. 2023; Chuang 2024).

Studies show the development of robots is a transformative leap in AI and robotics, having the potential to revolutionize many sectors, and education is one of them. They have the potential to teach students various subjects, engaging through emotion-perceiving technology or facial features like humans (Sapounidis, Tselegkaridis, and Stamovlasis 2024). They can be used to teach science, technology, engineering, mathematics and humanities as personal tutors, teaching assistants, peer learners, etc. (Kalaitzidou and Pachidis 2023). They advance education through more engagement, personalized learning, develop social skills, reduces stress etc., and reduce the work load of teachers (Atman Uslu, Yavuz, and Koçak Usluel 2023). Examples of these robots are Wonder Workshop's Dash and Cue, Softbank Robotics' Pepper and NAO, The LEGO Group's Lego Mindstorms, VEX GO Robot Kit, Kinesics and Synchronization in Personal Assistant Robotics, BeatBots' Keepon Robot, Personal Robots Group's Tega Robot etc. (Gottsegen 2024). Huge amount of capital have been raised by humanized robots startups (Andonov 2024). Many giants' technological firms are investing in the development of these robots and according to Citi analysts its market could grow to 7 Billion USD in coming 25 years. The advancement and research in artificial intelligence and technology is making the humanoid robots a near reality (Belcher 2024). A recent report from Goldman Sachs predicts that by 2023, the humanoid robot's market will touch 38 Billion USD, due to its significant use at workplace. It is important to highlight that according to the report, addition of 1.34 robots with 1000 workers have the potential to reduce injuries at workplace by 1.2 per worker, highlighting the benefits of automation (Kumar 2024). However, its adoption in education is facing various challenges, originating from human-machine interaction safety (Licardo, Domjan, and Orehovački 2024), robot's inherent character traits (Smakman, Vogt, and Konijn 2021), and inherent cultural values (Sethi et al. 2020). The problem due to cultural sensitivity in the design of humanized robots produces misunderstandings that lead to its failure in multicultural environment or population (Ge et al. 2024). Similarly, it is very difficult and challenging to programmed these robots for having desired character traits, leading to inconsistencies, and inappropriate interactions (N. Chen, Liu, and Hu 2024). In addition, ensuring psychological and physical safety is also a potential concern of these robot's adoption in education (Chatterjee, Chaudhuri, and Vrontis 2024). Though the benefits and technological advancements of humanized robots have explored by existing researches, an important gap exists concerning the challenge of safety, culture and character traits issues of these robots in education.

This research aims to fill this gap and find out how human-machine interaction safety, robot's inherent character traits, and inherent cultural values impact the adoption of humanized robots. The objectives of the study are:

1. To find out the relationship between safety issues and the adoption of humanized robots in education.
2. To find out the relationship between robot's character traits and the adoption of humanized robots in education.
3. To find out the relationship between robot's cultural values and the adoption of humanized robots in education.

The research offers valuable insights regarding the understanding of humanized robots' adoption for researchers, developers, educators and for the society in general. As the study investigates the complex dynamics that shape such adoption, it advances the understandings and discussion regarding robotics ethics, human-robot interaction, cultural studies etc. The findings also assist robotics developers to refine the production strategies and improve user its workplace experience.

Literature review

Theories. The theoretical foundation of the study is based on the Human-Robot Interaction Theory (HRIT) (Scholtz 2003), Social Cognitive Theory (SCT) (Schunk 2012) and Diffusion of Innovation Theory (DIT) (Miller 1962). These theories provide insights and understanding regarding the examination of the variables and relationships among variables for the adoption of humanized robots in education.

Human-robot interaction. This concept explores the interactions between humans and robots. It covers the interactions from multidisciplinary perspectives like psychology, design, artificial intelligence, programming, robotics, philosophy etc. to make the interactions more efficient and effective (Scholtz 2003). In the context of this research, it provides guidance to analyze and explore the interactions of students and teachers with humanized robots in terms of cultural values, and character traits (Babel et al. 2024). In addition, it also guides what should be incorporated into the humanized robots for ensuring safety and make them effective for classrooms (Haney and Liang 2024).

Social cognitive theory. Albert Bandura developed this theory, which focuses on the significance of observations in learning (Schunk 2012). It has a great use in education, psychology, and communication, and says that knowledge acquisition is directly related to the observation of other's individuals during social interactions, experiences etc. (Li et al. 2024). In the context of this study, this theory provides guidance regarding student's learning process and their adapting to robot's interactions (Arora et al. 2024). In addition, it also offers insights about how the cultural values and character traits of humanized robots influence the behavior of the students and teachers (Sampene et al. 2024). Similarly, it can also be used to explore how the character traits and cultural values of these robots are perceived by the students and teachers during interactions.

Diffusion of innovations theory. This concept was developed by Everett Rogers (Miller 1962). It provides insights regarding the process of technology diffusion across various cultures, and answers the how, why and the speed of new technologies adoption (Uzumcu and Acilmis 2024). In the context of this study, this theory is used to understand the process of humanized robots' adoption in education (Istenič et al. 2024). Through its lenses various factors like character traits (Lin, Jhang, and Wang 2024), safety (Chu and Ma 2024), and cultural aspects (Kou and Zhang 2024) were identified to have an impact on the humanized robot's adoption.

Humanized robots in education. In last few years, advanced technologies driven by artificial intelligence (Ahmad et al. 2022), interactive technology and robotics have been gained significant adoption in education (Sapounidis, Tselegkaridis, and Stamovlasis 2024). Humanized robots are designed to mimic human behavior and have started adoption in education as tools for enhancing learning experiences in class rooms (X. Wang et al. 2024). Many studies believe that the adoption of such robots is very beneficial for advancing education (Ching and Hsu 2024). It is evident from the literature that these robots are introduced to help teaching various subjects and skills in classrooms (Suhail et al. 2024). They possess the potential to deliver content and lecture in more personalized and dynamic manner as compared to human (Buchem, Sostak, and Christiansen 2024). Many studies show that they are capturing student's attention, improving their motivation and maintain their engagement (Grubišić and Crnokić 2024; Zhao et al. 2024; Yang et al. 2024). For example, Pepper and NAO have been teaching robotics and programming (Yun et al. 2024).

Similarly, researches indicate that in learning language, students are more comfortable to interact with technology while practicing a new language as compare to a human, and it decreases stress and anxiety students often feel while speaking to peers (Y. Chen 2024). Further, the seeking with robots improve vocabulary retention, pronunciation and skills related to conversation (F. Wang and Cheung 2024). Such robots also provide feedback in real-time and adapt to the student's proficiency level (Z. Zhang and Huang 2024). Humanized robots have also significant applications in special education. They are used to support special children like those with learning disabilities like autism spectrum disorder (Rizvi, Naba, William Wu, Mya Bolds, Raunak Mondal, Andrew Begel 24AD). These robots provide structured and consistent interactions, assisting them in developing communication and social skills in a designed environment (Dubois-Sage et al. 2024). In addition, the non-judgmental nature of these robots fosters progress in the emotional regulation and development of social interaction (Mehzabin et al. 2024).

Having many significant advantages in education, the adoption of humanized robots has some challenges. One study says that the use of advance technology in education reduces the human potential in making decisions, makes human lazy and produces safety concerns (Ahmad, Han, et al. 2023). Another study indicates that adoption of advanced technologies in some countries while not by others will increase the digital division among nations (J. He et al. 2024). Some studies show that many nations will not adopt it due to high cost (van Wyk, Kajimo-Shakantu, and Opawole 2024) (Ahmad, Alam, et al. 2023). They also have many programming and algorithmic issues, leading to unsafe human-robot interaction (Berx, Decré, and Pintelon 2024). Another issue is the development of emotional attachment between students and machines (Shutzman and Gershy 2023) (Tai and Dai 2022). Over-reliance on such technologies is another serious concern (Zhai, Wibowo, and Li 2024).

Another showed mixed results, where positive attitude and negative feelings were shown towards emotional AI by students. Older people showed more negative attitude towards emotional AI (Ho, Mantello, and Vuong 2024). It means that the people who have more awareness about attitude and emotions perceive emotional AI as a treat that may show unwanted emotions etc. Although, some studies appreciate "agreeable personalities and complaint attitudes" display from robots and believe that it creates positive learning environment (H. Wang et al. 2024). This is again an issue, if it always accepts what the learners say, will negatively shape the behavior of students. Concerns like privacy, biases, societal inequalities, data protection etc., are some of the significant generative AI challenges. Without addressing these challenges the successful adoption of AI technologies is not possible, and it is necessary for the engineers and developers to reduce them (Al-kfairy et al. 2024). Another study shows that factors like perceived ease of use, perceived usefulness, social influence, trust, and facilitating conditions influence the Chat-GPT adoption in education (Al-kfairy 2024). This clarifies the importance of trust, usefulness, and social influence, being the main prerequisite of character traits, cultural values and safety, in the adoption of advanced technology. Similarly, factors like attitudes, beliefs, feelings, opinion and perception, are some of the important psychological dimensions to be considered for effective human-robot interaction, which have a potential role in shaping perceived character traits, values, norms, etc. (Vagnetti et al. 2024).

It is an irrevocable fact that advance technologies like humanized robots have the potentials to reshape the education sector. Not only they have the capabilities to assist students having special needs etc., but can also provide personalized content according to the level of students. But the adoption of these humanized robots in education especially are facing several challenges. This research investigates only three major issues like safety, cultural inconsistency and unpredictable character traits issues and their relationships with the adoption of humanized robots' adoption in education.

Safety issue. Concerns related to safety is a critical issue in the adoption of humanized robots in education (Nnaji, C., Albeaino, G., & Okpala 2024). Safety is one of the main components of any technology to have, especially when human-machine interactions are necessary (Sousa et al. 2024). Researches show that safety is one of the major characteristics of any technology for its successful adoption and usage at workplace (FakhrHosseini et al. 2024). There are two types of safety concerns associated with the adoption of humanized robots in educational environment, physical (Islam et al. 2024) and psychological safety (Moffett et al. 2024). The challenge of physical safety is the primary concern while adopting these robots as they are designed and programmed to interact with students directly (Hasnine, Indurkhya, and Ahmed 2024). They must have to function safely around students and teachers without producing any harm. Similarly, technical malfunctions are also the serious concerns of humanized robots in an educational setting leading to the creation of unsafe situations for students and teachers; and disrupt the educational processes (Pedro 2024). Engineers and programmers are equipping them with advanced safety protocols and sensors to avoid harms but it is very difficult to make them foolproof and can lead to potential collisions and accidents (M. Singh et al. 2024). Another challenge comes in the form of psychological safety. In any educational setting, students need a friendly and a supportive environment to acquire education and learn effectively (Daphna Oyserman 2024). It is very difficult for humanized robots to behave and interact with students and teachers according to a particular situation, leading to emotional discomfort etc. (Okagbue et al. 2024). In addition, the usage of these robots further increases the dependency on technology leading to undermining essential interactions between humans and reduces human autonomy (Formosa 2021). This reduces the significant role of teachers in providing guidance and emotion support to students. This shows that despite the potential of humanized robots to improve education, they possess the challenge of safety (Hanna et al. 2022). Although developers and programmers are continuously working to improve the safety of humanized robots, it is still a challenge. As they have to interact with students and teachers, ensuring all type of safety is necessary and all types of safety risks must be mitigated for the successful adoption of humanized robots in education (H. He et al. 2022).

Character traits issues. The robot's character can be defined as the "consistent pattern of feeling, thinking and behavior

perceived by humans" (Pervin L, John O 2008). It is the primary source of providing social cues necessary for triggering individual intuitive responses during interaction with humans (Powers and Kiesler 2006). Studies show that it influences the level of satisfaction, people get from interaction with these robots (DC 1999). Robot's character is reflected during human-robots interaction through its social behavior and can be easily perceived by humans (C 2003). This study is limited to the inherent character traits, possessed by humanized robots due their algorithmic and design bias, or its limited knowledge. As character traits in humans are influenced by environmental influences, cultural values, and norms and vary across regions, it is not possible (at this time) to integrate and train humanized robots with all such traits. For example, people in Western cultures have traits like self-reliance and independence, while Asian prioritize family ties and group harmony (Arrindell 2003). These and other variations across nations shapes societal and personal character traits, which differs from nation to nation (Ting-Toomey 1999).

Concerns regarding character traits are also a significant challenge in the adoption of humanized robots in education (Złotowski et al. 2015). Character traits are very necessary when interacting with humans (N. Chen, Liu, and Hu 2024). Unlike humans, humanized robots have inconsistent character traits (Mays and Cummings 2023) that are not suitable for an educational environment. Humans have consistent personalities and character traits, they learned and adopted from the society over time, while humanized robots are designed and trained on predefined responses and information that are difficult to align with classrooms environments coherently (Maksimović, Jevtic, and Stošić 2024). This irregularity and inconsistency (Dobrosovestnova, Anna, Tim Reinboth 2024) confuse students and teachers, relying on predictable and stable interactions for building understanding and trust (Kopp 2024). Absence of emotional intelligence is another issue in the adoption of humanized robots in education (Vistorte et al. 2024). Specifically, in educational institutions compassion, empathy etc., are very important during human interactions (Smagorinsky 2024), and it is very difficult for humanized robots to show such traits (Kleinrichert 2024). Even if these robots simulate such character traits, there is a high chance of insincerity and superficiality as they do not understand the actual situations and needs of students (Torres 2024).

Although researchers are trying to appropriately train the robots for an educational setting, yet it is very difficult to train them like humans (Liebers et al. 2024). Due to any biased or programming error, they will exhibit exaggerated and inappropriate character traits due to no knowledge about a particular situation (Leichtmann 2021). There is a chance that a robot designed to be friendly becomes overly friendly and an authoritative robot become overly strict etc. and autonomy becomes in question (Methnani et al. 2024). Such inconsistencies and lack of character traits disrupt the educational environment. Similarly, it is not possible for humanized robots to navigate and understand complex social classroom dynamics (Pei and Nie 2018). Humans as teachers have to manage various types of conflicts, personalities, group dynamics etc., for ensuring a suitable learning environment by using their character traits (Savina and Fulton 2024). Lacking such character traits, humanized robots fail to manage and respond effectively in such situations (X. Zhang and Lee 2024). Lack of character traits hinders the successful adoption of humanized robots in education. It is necessary for developers to focus on making more advanced and suitable algorithms that guide humanized robots to manage, respond and tackle a particular situation. Without having a diverse and sophisticated character traits, successful adoption of such robots in education will remain a challenge.

Cultural issues. It is crucial for teachers to have knowledge about the subject and culture of the students in any educational setting (Wee et al. 2024). They are not only transferring knowledge about something but also their ethical and moral values which are different for different cultures (Chima Abimbola Eden, Onyebuchi Nneamaka Chisom, and Idowu Sulaimon Adeniyi 2024). Teachers also need to have an efficient knowledge about the needs and behavior of individual students coming from different cultural backgrounds (Karbeyaz, Aytekin 2024). Each student needs to be treated according to his own behavior, values and norms (Arneback and Jämte 2022). It is very challenging for humanized robots to provide equal personalized attention and education to each student (Bobro 2024). They may not understand and provide emotional support to each student equally like a human teacher (Coghlan 2022). These robots lack emotional intelligence, cultural knowledge etc., leading to their failure in providing support and empathy (Kleinrichert 2024; Smagorinsky 2024). The adoption of humanized robots faces a serious challenge due to the absence of embedded cultural values (Xia and LeTendre 2021). Such robots are designed to interact with people like humans mimicking human behavior. Many researchers believe that these robots offer many benefits in the environment of education but the absence of cultural attitudes and values could lead to a serious adoption challenge in an educational setting (Smakman, Vogt, and Konijn 2021). Although they are programmed and trained with knowledge about many behaviors and responses, yet covering a diverse user having different cultural backgrounds are not possible or at least very difficult (Yuan et al. 2021; Gasteiger, Hellou, and Ahn 2023). Human interactions are not possible without cultural nuances and include various expressions, gestures, language idioms etc., which is beyond the reach of a programmer or designer to train a robot on (AweRobotics 2024). And there is very high chance that such robots will respond and interpret cultural nuances inappropriately, leading to offenses and misunderstandings in the multicultural environments of schools and universities (Avelino et al. 2021). Another issue comes from the cultural biases that are unintentionally implanted by the developers during programming (Gordon 2020). This leads to biased interactions where certain cultural values and norms may get favor over others. Furthermore, it is very difficult to includes all cultural norms like empathy, behavior during complex social interactions, understanding and respecting others values etc., in these humanized robots which are very important for performing educational tasks like teaching etc.(Mansouri 2024). Lack of cultural knowledge, behavior, values and norms are one of the significant challenges in the successful adoption of humanized robots in education. These robots are not fully equipped to respond in a cultured manner or understand the norms, values, etc., of diverse cultures.

Theoretical mechanism. Although advanced technologies have many benefits in education, they never come without challenges.

Same is the case of humanized robot's use in education. Its adoption in an educational institute is facing many challenges, such as safety issues, lack of character traits and absence of cultural values. This study develops theoretical mechanism by integrating social cognitive theory, human-machine interaction and diffusion of innovation theory. By using these theories, a comprehensive framework was designed for understanding the complex relationship and influence of various factors on the humanized robot's adoption in education. The concept of HCI stresses on the use, design of technology, and the interfaces between users and technologies. This concept can be used to understand how factors like safety, character traits and cultural issues influence the usage and adoption of humanized robots. Parents, students and teachers might perceive that the use and adoption of these robots are unsafe, and may cause physical harm etc. In addition, these robots lack character traits, and cultural norms leading to a low student engagement, and misunderstandings. In addition to HCI, SCT focuses on the role of imitation, observational learning etc., in change of behavior. This theory provides understanding about the role of cultural values, character traits etc., on the adoption of humanized robots in education. Students and teachers observe the cultural norms and positive character traits from the society and adapt their behavior. If the interactions of these robots are not aligned with the character traits and cultural norms of students and teachers, they will not be adopted. Similarly, DIT explores the way innovations diffuse within a society and highlights the factors responsible for that diffusion. These factors are compatibility, relative advantage, trialability, complexity, and observability. Students and teachers will consider these factors before adopting humanized robots in education. if these robots demonstrate relative advantage in teaching and engagement, their adoption probability will be high. Furthermore, safety features and compatibility with cultural values and character traits will also be considered for adoption. The complexity of communication, understanding each other, interactions etc., also influence the use of humanized robots in education.

It is clear from the insights of these three theories that safety, character traits, and cultural norms are necessary factors for the adoption of humanized robots in education. If these humanized robots lack these factors, then it's a very challenging for the students and teachers to adopt them for teaching purposes. The theoretical framework as shown in Fig. 1 has been designed under the guidance of this theoretical mechanism.

Hypothesis. H_1: There is a relationship between safety issues and the adoption of humanized robots

H_2: There is a relationship between character traits issues and the adoption of humanized robots

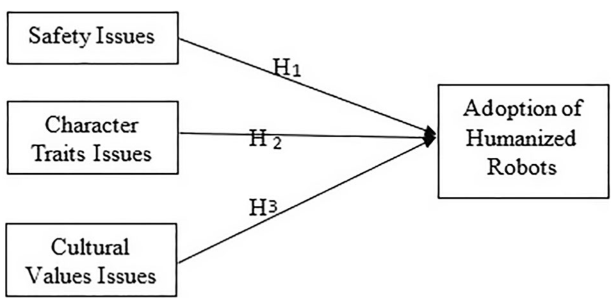

Fig. 1 Theoretical Framework for investigating the impact of safety, cultural and character traits issues in the adoption of humanized robots in education.

H_3: There is a relationship between cultural values issues and the adoption of humanized robots

Methodology

Research design. The philosophical roots of this study are rooted from the positivism philosophy, a pure scientific based technique which completely relies on the principle of science. The methodology used in the study is quantitative and a deductive approach was adopted for addressing the objectives. Secondary data was adopted from different renowned journals, books, and websites considering the quality of the materials. The primary data was collected from the participants of the study with the help of a closed ended Likert Scale questionnaire. All the measurement scales were adopted from the prior reliable studies which have developed these scales via rigor mechanism of the scale development. The details are given in Section "Research design" The questionnaire was circulated among the respondents via google form in Pakistan and China. A total number of the 620 respondents' data were collected, and then analyzed through Partial Least Square Smart (PLS-smart) software. PLS-SEM is one of the powerful tools used in technology related researches (Dash and Paul 2021) and has the ability of handling non-normal data, small sample sizes, and complex models (Muhammad Ashraf Fauzi 2022). It also provides more robust results. Furthermore, it is also helpful for hypothesis testing, and allows researchers to test theoretical models, multicollinearity, reflective-formative measurement models (Ramli, Latan, and Nartea 2018). It assesses validity of measurements by finding construct reliability, validity etc. Furthermore, it also integrates path analysis, factor analysis, and regression within a single analytical framework, providing a more comprehensive and flexible approach for the analysis of data (Dash and Paul 2021). The details of the tests and analysis are discussed in Section "Data Analysis"

Sample size and sampling techniques. The study used purposive sampling techniques for the collection of primary data, which is a non-probability sampling, effective for data collection from the target population. It was combined with stratified random sampling to reduce biasness in the collection of data. This technique is used to chose participants based on the purpose and objectives of the study (Davies, Martin Brett 2014). The respondents of the research were teachers (who taught at pre-graduate, graduate, post graduate level) and students (who study at pre-graduate, graduate, post graduate level) from different colleges and universities in China and Pakistan. The challenge of potential bias was primarily reduced through respondent selection criteria, like ensuring respondent's diversity (Etikan et al. 2016). For example, the sample was divided between Pakistan, and China, then it was further divided between teachers and students, level of education, age groups and gender. Secondly, purposive sampling was combined with stratified random sampling (Palinkas et al. 2015) to ensure responses from Pakistan, and China, teachers, and students, males and females, different level of education, and age groups.

After taking ethical approval and following ethical guidelines, proper consent was taken from all of the participants and those who accepted the consent participated in the survey. The number of total participants was 620 (the demographic details are given in section "Respondent Demography". The data was collected from 15^{th} June 2024 to 25^{th} August 2024. Although, it is difficult to achieve entirely bias-free method due to inherent involvement of subjectivity in research methods, yet certain practices were adopted to reduce bias and improve the reliability and validity of the findings. For example, the researchers clearly defined the criteria of selection according to the objectives of the research and

Table 1 Measures.

Variable	Items	Reference
Safety Issue	1. I am skeptical about the use and safety of humanized robots in schools. 2. I distrust the robot's suggestions. 3. I am suspicious about the use of humanized robots in schools. 4. Using the humanized robot could lead to dangerous and harmful consequences in classrooms.	(M. Y. Lim et al. 2022)
Character Traits Issue	1. I would feel uneasy if robots really had emotions. 2. Something bad might happens if robots developed into living beings. 3. I am concerned that the robots might have bad influence on children due to inconsistent character traits. 4. I am concerned about that lack of genuine emotional intelligence in humanized robots. 5. The robot might not be flexible and understandable like human in following the direction of our conversation.	(Nomura, T., Kanda, T., Suzuki, T., & Kato 2008)
Cultural Issue	1. I would not feel relaxed while interacting with robots that do not have specific cultural values. 2. I do not trust robots from friendship if they have any emotions due to lack of cultural values. 3. I feel discomforted being with robots having emotions. 4. Due to lack of cultural values, something bad could happen anytime while interacting with robots. 5. The robot might talk about irrelevant things in the middle of a conversation. 6. The robot might not understand many conversational topics having different meaning in different cultures.	(Ivanov, S., & Webster 2019)
Humanized Robots Adoption	1. I will be willing to use humanized robots in class rooms. 2. I will prefer humanized robots that are have more safety measure. 3. I will be willing to use robots that have understanding about our culture. 4. I will be willing to use humanized robot having character traits specific to our society and norms.	(Ivanov, S., & Webster 2019)

Table 2 Respondent Demography.

Country	Number	Percentage
China	350	56%
Pakistan	270	44%
Total	620	100%
Gender	**Number**	**Percentage**
Male	398	64%
Female	222	36%
Total	620	100%
Age Group	**Number**	**Percentage**
Below 30 Years	221	36%
30 to 45 Years	230	37%
Above 45 Years	169	27%
Total	620	100%
Study Level	**Number**	**Percentage**
Pre-Graduate	220	36%
Graduate	280	45%
Post Graduate	120	19%
Status	**Number**	**Percentage**
Student	320	52%
Teacher	300	48%
Total	620	100%

ensured its consistency. The participants were selected very carefully after communicating the rationale of the study to ensure transparency. The sample was divided in two countries, different age groups, study level and status to further minimize bias and ensure the representativeness of data and findings. This was done through combining random and quota sampling within the purposive sampling (MQ. 2014; Etikan et al. 2016).

Measures. The questionnaire consists of two sections. The first section consists of demographic questions such as country, gender, study level, age group, and status in terms of student or teacher. The second section includes the Likert-scale questionnaires of study's latent variables. The questionnaires for all four latent variables were adopted from previous researches. The details and source of each items are given in the Table 1.

Respondent demography. The demographic characteristics of respondents are given in Table 2. According to it, 350 (56%) respondents from China, and 270 (44%) respondents from Pakistan participated in the study. The Second section shows that there is a total of 620 respondents, comprising of 398 (64%) males and 222 females (36%). The third section of Table 2 shows the age wise distribution of the respondents, indicating that 221 (36%) respondents were below 30 years, 230 (37%) respondents were between 30 and 45, and the remaining 169 (27%) respondents were above 45. The fourth section of Table 2 shows the level of studies.

Data analysis

Reliability statistics. Reliability means the consistency of the scale. For the primary data, it is very important to confirm its reliability and validity before analyzing the data. SmartPLS can employ two basic types of reliability tests, i.e., items reliability and construct reliability. The measure used for the item's reliability is the outer loading values, having ideal threshold value of 0.7 but a value of the 0.6 is also acceptable if the overall reliability of the construct is significance. Table indicates that all the items of the four constructs have the reliability value greater than the threshold value which confirms that the scales have achieved the item's reliability.

The second reliability tool used in the SmartPLS is the construct reliability. This tool shows the overall consistency of the constructs. There are two common measures used for the construct reliability, i.e., Cronbach alpha and composite reliability. The threshold value for both measures is 0.7 and above.

Table 3 Items Reliability.

Construct	Cronbach's alpha	Composite reliability	Items	Outer loading
Character Trait Issues	0.878	0.916	CI1	0.900
			CI2	0.929
			CI3	0.846
			CI4	0.878
			CI5	0.746
Cultural Issues	0.896	0.924	CT1	0.868
			CT2	0.767
			CT3	0.892
			CT4	0.887
Humanized Robots	0.767	0.849	HR1	0.574
			HR2	0.895
			HR3	0.854
			HR4	0.820
Safety Issues	0.683	0.820	SI1	0.843
			SI2	0.741
			SI3	0.742

Those items having very low outer loadings values were removed from the analysis.

Table 4 Validity Statistics.

Constructs	Convergent Validity Average variance extracted (AVE)	Discriminant Validity Heterotrait-monotrait ratio (HTMT)
Character Trait Issues	0.732	0.718
Cultural Issues	0.673	0.583
Humanized Robots	0.544	0.692
Safety Issues	0.603	0.484

Table 3 shows that all the constructs have the reliability value greater than the threshold value which indicates that all the constructs have achieved their reliability and are suitable for further analysis.

Validity statistics. Validity explains the degree to which a concept is measured by a scale. In SmartPLS, there are two common methods of checking validity, i.e., convergent and discriminant validity. The convergent validity explains how much each construct is theoretical identical and related to another. The measure used for the convergent validity is the average variance extracted. The threshold value for the average variance extracted is 0.5 and above. Table 4 shows that all the AVE values are greater than the threshold value indicating that the scale has achieved the convergent validity.

The second test for the validity is the discriminant validity. This describe that how much the one construct of the model is theoretically different from the other construct of the model. The measure used for the discriminant validity is (Heterotrait-monotrait ratio) HTMT ratios. The threshold value for the HTMT is 0.85 or below. Table 6 shows that all the HTMT values are smaller than the threshold value which indicates that the model has achieved its discriminant validity.

Regression analysis. Regression analysis is used for checking the impact of independent variables on dependent variables. The measure used for the regression analysis is t and *p* value. The threshold value for the p is 0.05 and below while for the t is 1.96 or above. Table 5 shows the regression statistics of the relationships. All three hypotheses have higher p and t value than the threshold value which indicates that all the three hypotheses are supported by the findings of this study. While the beta value for each relationship defines the magnitude of the relationship. Figure 2 shows the tested model after regression analysis with values.

Table 5 Hypothesis Testing.

Hypothesis	Beta	T statistics	*P* values	Decision
H1: Safety Issues -> Humanized Robots	0.063	2.686	0.007	*Supported*
H2: Character Trait Issues -> Humanized Robots	0.325	4.874	0.000	*Supported*
H3: Cultural Issues -> Humanized Robots	0.530	7.904	0.000	*Supported*

Table 6 Model Fitness.

	Saturated model	Estimated model
SRMR	0.062	0.062
d_ULS	1.162	1.162
d_G	0.501	0.501
Chi-square	261.341	261.341
NFI	0.751	0.751

Model fitness. Model fitness describes the overall fitness of the model. This is an advanced measure to describe how much the model is fit if the same model is tested in different contexts. The study uses Standardized Root Mean Squared Residual (SRMR) for model fitness as it is based on structural equation modelling. The threshold value for the SRMR is 0.08 or below. Table 6 shows that the SRMR value for the model is 0.062, which is smaller than the threshold value, indicating the model fitness. Similarly, d_ULS stands for Unweighted Least Squares Discrepancy and assesses the discrepancy between the observed and model-implied correlation matrices by employing an unweighted least squares approach. There is no universal or fixed threshold value for it, but generally, lower values show a better fit (Shi and Maydeu-Olivares 2020). Table 6 shows value of 1.162 for this model, which suggests a small discrepancy and indicating that the model represents the data fairly well. The d_G stands for Geodesic Discrepancy and measures the geometric distance between the empirical and model-implied correlation matrices. Like d_ULS, it also has no fixed threshold value and smaller values show a better fit for the model. Table 6 presents the d_G value of 0.501, indicates a smaller value, and shows the validity of the model (Pls 2022). Another test used for assessing the model-implied covariance fits the observed one is the Chi-square test. Although a lower value indicates a better fit, it is highly influenced by sample size etc., and always interpreted along with other fitness tests. Table 6 shows the statistics of chi-square, having a value of 261.341. Apparently, the value is high but in a large sample size this does not indicate that the model is a poor fit. If the sample was small, then it could be an issue (Kline 2015). The NFI stands for Normed Fit Index and assesses the improvement of the model over the baseline model, where no relationships exist. Its values range between 0 and 1, and values near to 1 indicates a good fit. Table 6 shows NFI values of 0.751, which is below the acceptable threshold value of 0.9, and suggests that the model fit could be improved by adding other predictors and constructs, but with this sample size, it is acceptable (Bentler, P. M., & Bonett 1980; Kline 2015).

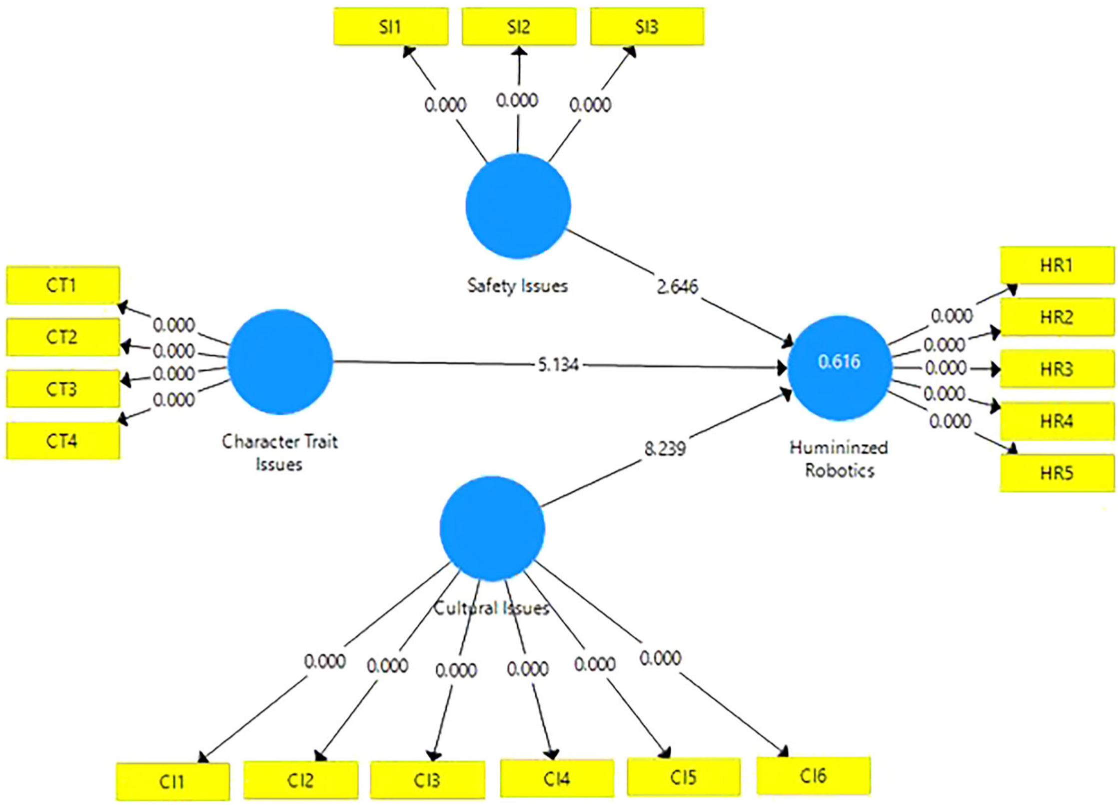

Fig. 2 Tested theoretical framework for investigating the impact of safety, cultural and character traits issues in the adoption of humanized robots in education.

Table 7 R Square.

	R-square	R-square adjusted
Humanized robots	0.618	0.616

Table 8 IPMA analysis.

Humanized robots	Importance	Performances
Safety Issues	0.755	34.634
Character Trait Issues	0.355	52.411
Cultural Issues	0.229	44.312

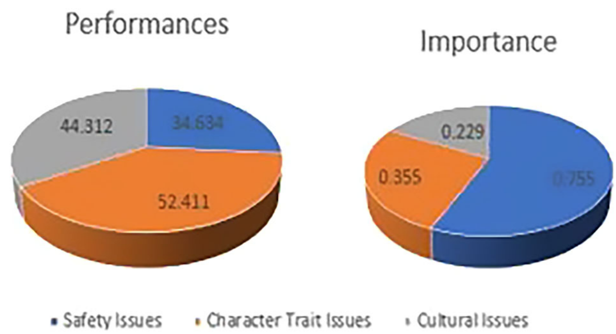

Fig. 3 Performance and importance of variables.

Coefficient of determination. The coefficient determination explains the percentage of variation in the dependent variable caused by the independent variables of the model. The measure used for the coefficient of determination is R square and its value ranges from 0 to 1 and is depends upon the nature of the data. For the secondary and time series data R square is always close to 1, while for the primary data the value of R square is mostly close to 0.5 or below. Table 7 shows that this model has an R-squared value of 0.61,8 which explains that 61.8% the variation in humanized robotics is due to the independent variable such as safety issues, character trait issues, and cultural issues.

IPMA analysis. IPMA stands for the importance and performance matrix analysis. This is an advanced test used in the SmartPLS to estimate the importance and performance of each independent variable for the dependent variable. Table 8 and Fig. 3 shows that the most important variable for the humanized robot is safety issue while the most performed variable for it is character traits issues.

Multi Group Analysis (MGA) based on gender. MGA is an advanced technique used in the SmartPLS to compare the results of the study findings based on two different categories of the population. This shows the homogeneity of the collected data that how much the data of the study is spread over. Table 9 shows the gender wise comparison that how the results of the study differ due to male and female. The measure to identify the difference is the p value. The threshold for the p value is 0.05 or below. Table 9 shows that all the relationships have a p value greater than the threshold value which indicates that there is no difference in the results of the study based on the gender.

MGA based on country wise. Table 9 also shows the country wise comparison of how the results of the study differ due to Pakistan and China. The measure to identify the difference is the

Table 9 Multi group analysis.

Gender wise

	Beta-diff (Male - Female)	*p*-value (Male vs Female)
Character Trait Issues >>> Humanized Robotics	−0.025	0.137
Cultural Issues >>> Humanized Robotics	0.001	0.912
Safety Issues >>> Humanized Robotics	−0.013	0.668

Country wise

	Beta-diff (China - Pakistan)	*p*-value (China vs Pakistan)
Character Trait Issues >>> Humanized Robotics	−0.035	0.056
Cultural Issues >>> Humanized Robotics	−0.012	0.204
Safety Issues >>> Humanized Robotics	−0.101	0.373

p value. The threshold for the *p* value is 0.05 or below. Table 9 shows that all the relationships have a *p* value greater than the threshold value, which indicates that there is no difference in the results of the study based on the country of the respondents.

Discussion

The study investigates the impact of safety concerns, character traits, issues, and cultural values issues with the adoption of humanized robots in education. It is based on three hypotheses, where the first hypothesis says that there is a relationship between safety issues and the adoption of humanized robots. The findings also show that there is a relationship between safety issues and the adoption of humanized robots with a beta value of 0.063, t-statistics 2.686, and significance value of 0.007. Previous research has also shown similar results (Giallanza et al. 2024; Sharma et al. 2024). This shows that ensuring safety is an important factor for the adoption of humanized robots in education. Not only the physical safety arising from the possibility of robot malfunctions due to error etc., the psychological safety must also be assured (Zacharaki et al. 2020). The second hypothesis says that there is a relationship between character traits issues and the adoption of humanized robots. The findings also show that there is a relationship between character traits issues and the adoption of humanized robots with a beta value of 0.325, t-statistics 4.874 and a significance value of 0.000. Previous research has also shown similar results (Seyitoğlu and Ivanov 2024; Kaya et al. 2024). The results indicate that the possibility of character traits issues will be a potential barrier in the adoption or introduction of humanized robots in education. Developers, designers, and educational institutions must ensure that the humanized robot functions according to the expectations and the behavior of the students and teachers (Liu et al. 2024). The third hypothesis says that there is a relationship between cultural values issues and the adoption of humanized robots. The findings also show that there is a relationship between cultural values issues and the adoption of humanized robots with a beta value of 0.530, t-statistics of 7.904, and a significance value of 0.000. Previous research has also shown the need and important role of culture in the adoption of humanized robots (Showler 2024; Kou and Zhang 2024). It demonstrates that the cultural values to be shown by the robot are also significant factors for the adoption of their adoption in education. Robots must be trained and programmed according to the cultural values of the society where it is going to be implemented (Sparrow and Howard 2021). Furthermore, students and teachers should be given training regarding safe human-robot interactions, in addition to awareness about the possible cultural values to be shown by the robots (V. Lim, Rooksby, and Cross 2021). Keeping in view the importance of advanced technologies in education, it is necessary to develop and design a humanized robot that is safer, well-trained, and programmed according to the character traits, and well aware of the cultural values of the humans interacting with it (Staffa, D'Errico, and Maratea 2024). This can be achieved through the integration of advanced safety protocols, sensor systems, programming, etc., within the robots. It should be designed in such a way to reduce injuries and accidents if there are any malfunction,s etc. Similarly, due to the lack of genuine emotions and feelings, humanized robots may exhibit inappropriate and insistent character traits, which can lead to frustration and confusion. For example, if a robot becomes friendlier or more authoritative, it will disrupt the learning environment. Therefore, they need to be programmed very carefully and thoroughly (Prather et al. 2023). In addition, they cannot adapt and respond like human teachers, which is also a significant cause to hinder adoption. This issue is very complex and needs a lot of research to be explored and mitigated. Moreover, having cultural values is also very important for the adoption of humanized robots in education. Ensuring cultural values in robots is beyond the approach of one-size-fits-all, and it is very challenging to train a robot with multiple cultural backgrounds. This cultural insensitivity produces many offenses, misunderstandings and reduces engagements. While they have the potential to reshape education, resolving the safety, character traits, and cultural values issues is necessary for their adoption in education. A thorough approach is needed that ensures safety, character traits, and cultural values to understand the potential of robotics in education.

The findings extend HCI, SCT, and DIT by offering new insights and extending the current cultural, psychological and ethical barriers that influence the adoption of technology in education organizations. The findings extend the current understanding of HCI and highlight that human-like characteristics may possibly evoke psychological resistance among users. This is called Uncanny valley Effect, "a phenomenon where robots with near-human resemblance elicit discomfort and rejection from users" (Mori, MacDorman, and Kageki 2012). For example, users will perceive robots having more human-like traits are deceptive and will lead to low engagement. These findings suggest that HCI frameworks need to seriously consider psychological factors that lead to character traits, values, norms etc., alongside other usability factors, and focus on a more balanced humanized robot design where human-like characteristics and features enhance the acceptance of humanized robots. Similarly, SCT says that the interaction of environmental, social and personal factors shapes the behavior. The theory has been traditionally used for understanding how factors like an individual's self-efficacy, social reinforcement, and observational learning influence the adoption of technologies (Bandura 2008). The findings of this research validate and highlight the importance of cultural values and character traits in shaping users' behavior regarding humanized robots' adoption. For instance, robots that act like humans in a conflicting and inappropriate manner with the cultural values may be considered unacceptable in conservative cultures but may be ignored in other cultures. Therefore, the integration of cultural knowledge is significantly important for humanized robots, particularly in education, where the audiences are youngsters. This will lead to resistance in humanized robots' adoption. Therefore, the findings suggest the integration of an important determinant of cultural adaptability into the design of humanoid robots. This also highlights the importance of tailored and localized strategies for the successful adoption of such robots according to the societal norms of that society. The findings of this research also extend the insights of DIT theory, which originally focused on the diffusion of a technology in a particular region. The theory focuses on the patterns through which new technologies spread among people. The key players are innovators, early adopters, early majority, late majority, and laggards (Rogers 1962). For example, in the case of humanized robots' adoption in the education sector, if the early adopters are satisfied with the adoption of humanized robots in education, then the majority will adopt this, and vice versa. This research extends the patterns of technology adoption as suggested by DIT by integrating them with cultural values, character traits, and safety measures. For example, the early adopters will also consider cultural values, character traits, and safety measures in addition to other factors while adopting humanized robots in education. The study integrates HCI, DIT, and SCT into a single theoretical framework and extends their current understandings by focusing on the challenges coming from character traits, safety issues, and cultural perceptions. And suggest that the adoption theories need to evolve in such a manner to address factors like cultural adaptation, psychological comfort, cultural adaptation, and safety.

Theoretical implications. The findings have the following valuable theoretical implications.

1. This study integrates HRI, SCT, and DIT in a single theoretical framework, never been developed or tested before for the adoption of humanized robots in education.
2. The findings extend the current understanding of HCI by highlighting the importance of psychological factors that lead to character traits, values, norms etc., alongside other usability factors, and on a more balanced humanized robot design.
3. The findings validate SCT and suggest the integration of an important determinant of cultural adaptability into the design of humanoid robots.
4. This research extends the patterns of technology adoption as suggested by DIT by integrating them with cultural values, character traits, and safety measures.
5. The findings show that expansion of existing theories and development of new theoretical frameworks are needed for a thorough understanding about the adoption of humanized robots.
6. Furthermore, it also underscores the significance and need of safety, positive character traits, and cultural sensitivities for the development and broader acceptance of such technologies.

Managerial implications. The study has implications for managers facing challenges in the successful adoption of humanized robots due to safety concerns, character traits issues, and cultural issues.

1. The findings highlight the need for safety measures, protocols, and training to be provided to students, teachers etc. for ensuring safe human-robot interactions in classrooms.
2. The findings also show that engineers and designers of humanized robots must consider safety measures, protocols, and appropriate training to ensure safety.
3. The findings also emphasize the importance of for students, teachers etc. for ensuring safe human-robot interactions in classrooms.
4. Developers of such robots must collaborate with managers to ensure appropriate and consistent character traits and cultural values are shown by the robots according to the educational objectives.
5. In addition, multi-cultural training must be provided to developers, students, teachers etc., to advance their understanding regarding different cultures and character traits to ensure an inclusive learning environment.

Practical implications. The results also have practical implications coming from the necessity of safety, character traits, and cultural values to be integrated in the development, design and adoption of humanized robots.

1. The technology developers must ensure the safety features and must invest highly in research related to the cultural, character, and safety capabilities of humanized robots to be deployed in education.
2. Furthermore, the students and teachers also need to have enough resources and skills to interact with these robots effectively and safely.
3. Content relevant to cultures and positive human character traits must be integrated to the robots, and students must be provided with awareness about robot-assisted educational experiences.

Societal implications. The findings of the research also have important societal implications in the context of social and cultural factors towards the adoption of humanized robots in education.

1. This new technology has a significant role to shape educational experiences.
2. The findings provide insights to address the safety concerns for building confidence and trust for the adoption of such robots.
3. Furthermore, the findings also stress on ensuring cultural diversity and humanized traits during human-robot interactions in education.

Conclusion

Like other areas, robotics technology has the potential to revolutionize education. But unlike other advanced technologies, the adoption of robotics technology in the form of humanized robots in education has to face more serious challenges, as it has to mimic humans. The study examined the relationships of safety concerns, character traits issues, and cultural issues with the adoption of humanized robots in education. The results show that safety concerns, character traits issues, and cultural issues influence the adoption of humanized robots in education. Safety is one of the concerns to be addressed for the adoption of humanized robots in education. If individuals see that there is less or no safety issues, then the chance of the humanized robot's adoption will be high. Similarly, humanized robots must have character traits according to the society and individuals it serve. If individuals believe that the robot has no character traits according to their values and norms, they will be reluctant to accept it. Lastly, humanized robots must also have cultural understandings of the students and teachers they serve. They must have the knowledge to understand their emotions, particular cultural words, values, norms, etc. for their adoption. All three factors provide insights about the importance of safety (both physical and psychological), positive character traits, and cultural understandings to be integrated into a humanized robot for its adoption in education.

Recommendations. The designers should ensure safety features in humanized robots. They must work on the training, programming etc. of the robots, to increase physical and psychological safety. Similarly, humanized robot applications should be backed and trained by advanced and secure algorithms to ensure its safety during interactions with students and teachers. Moreover, humanized robots must be provided with extensive cultural and behavioral knowledge of the society, geography, etc., of the place where it will be used. It must be trained to show cultural and behavioral respect to all. Last but not least, students and teachers should be trained before interacting with humanized robots.

Limitations and future research. Adoption of humanized robots, especially in education, is new, and it is very difficult for any research to cover all aspects related to this in a single paper and when there is very little work available. This research provides a base for further studies in the context of humanized robots in education. Furthermore, the scope of the study can be extended to more technologically advanced countries the check the generalizability of the results. Other factors can be integrated into the model in future studies.

Data availability

Data is provided within the manuscript or supplementary information files.

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Author contributions

SFA and ZU. wrote the main manuscript text, FU and MI collect the data and do analysis, and MG and ABAA. did the analysis, edit the text. All authors reviewed the manuscript

Competing interests

The authors declare no competing interests.

Ethical approval

The evaluation survey questionnaire and methodology were examined, approved, and endorsed by the research ethics committee of Gwadar University, having a project number 2024/UG/ORIC/P-2 on 10th January 2024, and by Beijing University of Posts and Telecommunications, Beijing, China on 21st Feb 2024 with the same project number. The study meets the requirements of the National Statement on Ethical Conduct in Human 28 Research (2007). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed consent

The informed consent was approved and endorsed by the research ethics committee of Gwadar University, having a project number 2024/UG/ORIC/P-2 on 10th January 2024, and by Beijing University of Posts and Telecommunications, Beijing, China on 21st Feb 2024 with the same project number. Informed consent was obtained from all participants before the data were collected. We informed each participant of their rights, the purpose of the study, and to safeguard their personal information.

Additional information

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