Perception of Robotics in General and in Higher Education for the Industry 4.0 Era

Hasan TINMAZ
Woosong University, South Korea
htinmaz@endicott.ac.kr

Mina FANEA-IVANOVICI
Bucharest University of Economic Studies, Romania
mina.ivanovici@economie.ase.ro

Abstract
Robotics has largely developed lately and is currently being used for various types of industries, e.g., manufacturing, military, medicine, education. The purpose of this study is to explore the general perception of robotics, with a focus on its application in higher education in the Industry 4.0 era. Using simple convenience sampling, a number of 365 valid responses were collected from the students enrolled in a South Korean university and exploratory factor analysis was employed. Out of an initial number of 56 items, 33 were retained using the principal component analysis, and six factors were revealed: emotional robots, instructional support robots, instructional subordinate robots, labor force robots, progressive robots and scary robots. Perceptions of male students differ significantly from those of females in some respects – the former believe more that human labor will be replaced by machine labor, that robotics could be helpful in higher education, and that the development of robotics should be promoted by countries. South Korean students, unlike non-South Korean ones, consider to a larger extent that robots can have emotional functions, that they might take the place of human labor and could reduce the job opportunities, while admitting robots' capacity of making life easier and of creating mutual human-robot learning opportunities. The discussions and implications provided will be useful to managers and policy makers, particularly in education.

Keywords: robotics; robot; perception; education; Industry 4.0; South Korea

JEL Classification: I23; O14

DOI: http://doi.org/10.24818/ejis.2023.13

1. Introduction

Industry 4.0, alternatively known as the Fourth Industrial Revolution, represents the upcoming stage in the digital transformation of the manufacturing industry. This transformation is propelled by disruptive forces such as the increased prominence of data and connectivity, advancements in analytics, the interaction between humans and machines, and enhancements in robotics (McKinsey & Company, 2022). Thus, the advent of the Industry 4.0 era has led to a widespread penetration of technology in all aspects of life, which has rendered the quasi-totality of activities more efficient. The most recent developments in IT, i.e., artificial intelligence, cloud computing, 3D, 5G, Big Data, have changed the way operations are performed, and robotics is keeping abreast with these evolutions. Although the industry has been using robotics for decades, it is only recently that a new generation of robotics and robotic

Received: 21 May 2023; Revised: 30 September 2023; Accepted: 1 November 2023

applications have arisen (Bayram & Ince, 2017). The multiple improvements in robotics that took place over time have required a redefinition of the term. Trevelyan (1999, p. 1211) suggests that robotics should be defined as "*the science of extending human motor capabilities with machines*". Robotics is an interdisciplinary subject found at the crossroads of science, engineering and technology, which designs, builds and operates machines or robots, which substitute or replicate human action (Builtin, 2019).

Gasparetto (2016) presents the history of robots from ancient times to the Industrial Revolution of the 18th century. He highlights that robots are not a new concept, and that they were designed to replace humans for heavy and repetitive tasks. The author states that the various inventions throughout time and their prototypes can fall within the category of robots. Gasparetto and Scalera (2019) classify industrial robots into four generations: the first generation from 1950 to 1967, which were programmable machines that did not have the capacity to control the execution of tasks; the second generation from 1968 to 1977, which were basic programmable machines with limited self-adaptive behavior and with the capacity to recognize the external environment; the third generation from 1978 until 1999, which included robots that could interact with the operator and the environment via complex interfaces; and the fourth generation from 2000 to date, which have high levels of intelligent features.

Sundurov et al. (2021) mention that the robot concept was coined in the 1920s, with the first industrial robots being created in the middle of the 20th century, and that the bases of the robotics definition and science being laid in the late 1970 and early 1980s. Despite the ancient use of robots, Trevelyan (1999) tracks the roots of robots back to science fiction, and calls for anchoring robotics into reality. In fact, it is through the works of Karel Čapek and Isaac Asimov (Gasparetto & Scalera, 2019) that the term was first introduced. The science of robotics was born when mechanical and control engineers saw opportunities in the nascent artificial intelligence. Since then, a lot of debate has been going on about how to define robotics. Nevertheless, it is expected that the global market size of industrial robots will expand – from 43.8 billion USD in 2021 to 70.6 billion USD by 2028 (Statista, 2021).

Siciliano and Khatib (2016, p. 1) make the case for the broad use of robots, underscoring that we can find "*[r]obots on Mars and in oceans, in hospitals and homes, in factories and schools; robots fighting fires, making goods and products saving time and lives*". Existing research has it that the scope of robotics is very large, including numerous categories of robots, with different purposes, mobility, autonomy, degree of danger, cyber-physical systems with artificial intelligence (Sundurov et al., 2021).

Considering the broad range of activities robots can perform, researchers have proposed the inclusion of robotics in national strategies. By way of example, Christensen (2012) suggests that the United States should design such a strategy by field of activity: manufacturing and logistics; healthcare and medicine; service robotics and emerging technologies. This need arises from the fact that the country strives to gain supremacy in a market dominated by Japan, Europe and South Korea.

Because robots and robotics have advanced into all areas of activity, including in education, we consider it is important to investigate the users' perceptions about robots and robotics before introducing them in the learning process. Knowledge of perceptions about robotics can identify the main barriers and opportunities and will ensure smooth adoption of available technologies. The aim of this paper is to analyze robotics perceptions of higher education students currently completing their higher education studies in South Korea. To the best of our knowledge, there is no research investigating higher education students' perception about robots, therefore this study aims at answering one main research question, i.e., *What are higher education students'* *perceptions about robots and robotics with a focus on their benefits from a professional, educational and other uses, but also impediments in their use?*

The remainder of this paper is structured as follows: the literature review will reveal the main categories of robots from the point of view of their benefits in various fields – emotional, instructional support, instructional subordinate, labour force, progressive, but also from the perspective of impediments in their use – scary robots. Further, the paper continues with sections dedicated to method, results, and discussion and conclusion, the latter including practical and policy implications. Last but not least, further studies and limitations end the paper.

2. Literature Review

There continues to be a lack of consensus regarding the definition of a robot. A substantial body of literature, particularly within technical fields, addresses robots and robotics in a comprehensive manner. Besides, existing robotic taxonomies classify robots based on various criteria, including functionality, design, application, and capabilities. Notably, none of these taxonomies explicitly addresses the educational utility of robots as a distinct category. Application-based taxonomies focus on areas such as medicine, agriculture, search and rescue, and space exploration (Haidegger, 2021).

In our work, we will next present the main types of robots with a specific emphasis on their educational utilization, as found in the literature and grouped by the authors, according to the benefits in various categories of activities.

Emotional Robots

Newer generations of robots have evolved to englobe more user-friendly services. One such service refers to the provision of emotional services instead of passive services, according to Kang et al. (2007). The authors state that emotional robots used in children's education have the capacity to create a sense of intimacy and can help contribute to the emotional stability of the subjects of education. Such robots have been designed to be used both for children's activities and therapy, and they enable emotional responses between children and robots. Additionally, having the capacity to decipher action and to use artificial emotions, such robots are expected to be successfully used in childcare services. In a learning context, robots can represent a faithful audience in the dialogue between instructors and students or between parents and children (Chen et al., 2009). Extant research indicates that robots designed to be emotional can enable interaction of affective and intelligent nature (Zhang et al., 2006).

Instructional Support Robots

Robots can support the teaching process by playing the role of teaching assistants to be used both by instructors and by parents. Such devices are designed to play a certain role, which is assigned previously, i.e., talking instead of the teacher or parent, or to cooperate with the instructor (Chen et al., 2009). Campos (2017) posits that robots used for educational purposes have the potential to bolster creativity among students and to foster other learning skills among them, which are sufficient reasons to introduce robotics in the education system. Moreover, developing imagination and communication skills in students can be achieved using robots in a tailor-made fashion, at individual level (Suzuki & Kanoh, 2017). Support of the educational process includes, but is not limited to, learning and teaching computer programs, Sciences, Mathematics, languages (Chen & Chang, 2008). Based on these benefits, it has been suggested that educators should include robotics, among other new technologies, such as Internet of Things sensors and actuators, programming languages and other hardware devices, to generate positive attitudes towards inclusion of robots in education (Hu et al., 2022).

Instructional Subordinate Robots

The idea of replacing humans by robots in education has already been advanced in the specialized literature. As such, Suzuki and Kanoh (2017) reiterate this idea, on account of expected benefits, which include fostering students' imagination. Suzuki and Kanoh (2017) claim that using robots to substitute humans in education was successful in their experiment involving boosting students' imagination by providing hints by robots, but this success actually depends on the interest shown by students in this technology. Other researchers (Li et al., 2016) indicate that robots could be used for video presentations, thus replacing human lecturers, and that this substitution could lead to shorter time and lower costs associated with lecture design and delivery. However, Li et al. (2016) admit that adoption and effective use of robot lecturers instead of human lecturers need to overcome two challenges: perception towards use of robots and proper design to facilitate acceptance. Sinatra et al. (2021) go even further, stating that education tends to move into virtual environments, and human instructors are either assisted or replaced by virtual agents. To achieve the intended outcomes, the authors (Sinatra et al., 2021, p. 4) signal the need for social fidelity, which refers to "*socially-relevant attributes of virtual characters and the realism of these social attributes*", and includes "*personalized language, politeness, attention, feedback, social memory, personality, interactivity, and gestures*".

Labor Force Robots

Technology makes life and work easier. However, adopting technology, including robotics, by replacing human labour, may pose problems of acceptance in the society. Recent research has shown that there is a preference for human labour as opposed to robotic labour in symbolic consumption contexts (Granulo et al., 2021). Symbolic consumption refers to those goods and services that reflect the consumer's beliefs or personality and that highlight product uniqueness. At the other end of the spectrum, certain industries require automation and robotization, especially when the population does not want to engage in such activities, as is the case of agriculture (Wang et al., 2021). A study conducted on ten countries has shown that robots have replaced human labour especially in routine tasks, which would normally be performed by low skilled or unexperienced workers or by women, mostly in manufacturing, and that demand for labour rose in services, for jobs that high skilled and experienced workers, mostly males, perform (Blanas et al., 2019).

Progressive Robots

Problem-solving skills have been listed in the extant literature among the main benefits of using humanoid robots in education (Chen & Chang, 2008). But progressive robots can go as far as to be able to get involved in mutual learning with humans. Ikemoto et al. (2012) describe the most developed robots as having the capacity to interact physically with humans by adapting their behaviours accordingly. Socially assistive robots can be used in therapy thanks to features such as user-centrality and participatory design, and a propensity towards mutual learning (Winkle et al., 2020). Progressive robots in our study represent a category known for advanced capabilities and adaptability in education, actively engaging with students and tailoring their interactions based on individual needs. In contrast, 'Instructional Support Robots' primarily assist teachers in content delivery, with some overlap but lacking the proactive adaptability of progressive robots.

Scary Robots

Despite the irrefutable advantages they bring in various activities, perceptions regarding robots may represent an obstacle in extending their use to other areas. Besides the concerns about losing jobs on account of robots' use, their resemblance with humans may scare users. The robot embodiment as a female humanoid 'working' as a receptionist in a Japanese hotel produced negative sentiments to visitors – it was perceived as both scary and horrible (Io & Lee, 2019). Other studies show that robots can affect trust and harm mental health and emotional wellbeing (Fratczak et al., 2021). In healthcare, fears revolve around lack of reliability, safety, likability, and the sense of caring (Nyholm et al., 2021). Overall, disagreeable appearance, lack of safety and distrust appear to prevail as sources of scare in using robots.

Previous studies reveal that gender plays a significant role in perception of robotics. Dautenhahn et al. (2006) posit that gender may affect subjects' attitudes towards and perception of robots, and since those perceptions will influence their expectations with regard to robots (Schermerhorn et al., 2008), a comparison of female and male participants on robotics perception has become necessary for educational-related stakeholders when they are considering applying robotics education in higher education institutions.

Besides, studies indicate that the origin country of a technology often determines its basic cultural alignment, therefore a form of ethnocentricity results that might generate problems with technology acceptance in a different target country (Straub et al., 2002). Different countries have varied cultural background and are on a diverse stage of development of economy and technology, which might influence participants' perception of robotics.

Last but not least, in the realm of robotics, several distinct categories have emerged, each with its unique purpose and characteristics. Emotional robots are designed to recognize and respond to human emotions, fostering empathetic interactions in instructional contexts. Instructional support robots primarily assist educators by delivering content and providing supplementary support during instructional activities. Instructional subordinate robots, on the other hand, assume a more passive role, aiding students in subordinate capacities, often through repetitive tasks. Labor force robots are typically employed to automate manual labour tasks, enhancing efficiency. Progressive robots stand out for their advanced adaptability and dynamic engagement with students, tailoring interactions based on individual needs and progress. Lastly, while not a formal category, scary robots evoke fear or discomfort due to their design, behaviour, or intended purpose, often challenging the boundaries of human-robot interaction, even in educational contexts. These distinctions vividly illustrate the diverse roles and impacts of robots in educational settings.

3. Methods

Sampling and Data Collection Procedures

A number of 365 effective copies of questionnaires, out of 500 copies dispatched in total, were filled out by university students from the international schools of a university in the central part of South Korea, which is widely known as high-tech country. The convenience sampling was used for the study, which is also endorsed when the main objective is to collect information from participants who are easily accessible to the researchers for study participation (Etikan et al., 2016).

One of the researchers visited different classes, described clearly to the participants what the questionnaire is about, asked whether they would voluntarily like to fill out the survey, and stated there is no penalty for refusal to participate. As the city where the university is based is the center of Korean technology and is taking the lead in the robotic industries, the participants here had a good understanding of robotics and were glad to participate in the survey. A number of 500 copies of questionnaires in total were handed out to students, who were asked to fill out the survey within one week and then gave it back to the researcher anonymously. A week later, 365 effective copies of the survey were collected from the participants. The researchers entered the collected data to SPSS.

Exploratory factor analysis, which is often implemented to explore the underlying factors from a set of observed study variables (Jr. Hair et al., 2019), was conducted for the study. A major discussion of explanatory factor analysis is the minimum sample size, usually based on the minimum necessary subjects to obtain reliable results from the statistical procedures (Pearson & Mundform, 2010). A range of recommendations have been made concerning the ideal sample size as five subjects per variable – at least 100 subjects, irrespective of the number of variables (Gorsuch, 1983), the sample size should be at least 200 (Guilford, 1954), three to six respondents for each variable, at least of 250 participants (Cattell, 1978) or any large sample, preferably several hundred (Cureton & D’Agostino, 1983). Based on the recommendations stated above, a number of 365 participants would be considered as sufficient for a study with 56 variables.

Study Instrument

In this study, the authors meticulously crafted a data collection instrument in the form of an English-language questionnaire. This questionnaire was thoughtfully developed by drawing upon the extensive insights gained from a comprehensive literature review focused on the perception of robotics and its relevance in educational contexts. The primary objective behind the creation of this questionnaire was to gain a deep understanding of the overarching views held by university students concerning robotics and its application within the realm of higher education. By constructing a well-structured questionnaire informed by the existing body of knowledge, the authors aimed to capture a holistic representation of the students' perceptions, thereby shedding light on the multifaceted dynamics between robotics and academia in the context of higher education.

The questionnaire was not finalized until several revisions had been made to format, wording, and expressions. Subsequent to the survey design, a language expert whose mother tongue is English was asked to check whether there are any grammatical or expressional mistakes for the survey. Then, a pilot test was carried out with three international students in this university.

The questionnaire is mainly comprised of two parts: (i) three literature-based demographics questions about participants’ gender (female and male), country, and year of study (freshman, sophomore, junior and senior), and (ii) fifty-six items on five-point Likert scale (from Strongly Agree to Strongly Disagree) questions on robotics in general and application of robotics in higher education. After data collection and input, reliability analyses were conducted to examine the Cronbach alpha and six rounds of exploratory factor analysis were made for data validity. Finally, twenty-three questions were excluded from the question pool and thirty-three items remained for further analysis.

Data Analysis

The survey papers were checked for their full completion and numbered before data input and analyses. Of all the returned questionnaires, a number of 365 copies were considered as effective and used for further data analysis.

To investigate the participants' general perception on robotics and its application in higher education, descriptive analyses were made. As there are two different parts, i.e., demographics and Likert scale questions, different statistical analyses were applied. For the demographics part, frequencies of gender, country, and year of study were tabulated, and a contingency table of gender and year of study was presented with comments accordingly.

For the Likert-scale questions part, mean score and standard deviation were initially calculated and tabulated. Furthermore, exploratory factor analysis tests on SPSS were conducted in order to figure out what factors might affect the general perceptions of robotics and its application in higher education. Subsequent to six rounds of factor analysis, twenty-three questions were deleted, and six factors were generalized as emotional robots, instructional support robots, instructional subordinate robots, labour force robots, progressive robots and scary robots.

Since reliability and validity are used for enhancing the accuracy of the research (Tavakol & Dennick, 2011), each group of factor questions was checked for reliability with Cronbach Alpha as a whole and for each item. Statistics reveal Cronbach coefficient of $\alpha=0.86$ for 33 items and reliability for each item is greater than 0.60. The following values were calculated for the factors; factor 1: Emotional Robots ($\alpha=0.77$), factor 2: Instructional Support Robots ($\alpha=0.76$), factor 3: Instructional Subordinate Robots ($\alpha=0.79$), factor 4: Labor Force Robots ($\alpha=0.62$), factor 5: Progressive Robots ($\alpha=0.64$), and factor 6: Scary Robots ($\alpha=0.67$). As Ursachi et al. (2015) stated out that a general accepted rule is that Cronbach Alpha of 0.60 - 0.70 specifies an acceptable reliability level, and 0.80 or greater a very good level, the reliability statistics implies a reliable result for further analysis.

Furthermore, comparisons were made among the groups of items. More precisely, independent samples t-tests were carried out on the demographics part to check whether there is any general difference between female and male participants as well as South Korea and non-South Korea participants or not. Therefore, the researchers also employed independent samples t-test to check whether there is any difference for participants of different nationality on robotics perception.

Apart from independent samples t-test, the researchers have further conducted a one-way ANOVA test to check whether there is any difference for participants from different years of study.

4. Results

This study was conducted to explore what the general perceptions of college students on robotics and utilization of robotics in education are in the Industry 4.0 era. The simple convenience sampling method was chosen for the study. A number of 500 copies of Questionnaire on Perceptions of Robotics and Education in the Industry 4.0 Era in English were printed and dispatched to college students at a private university in South Korea. The questionnaire was anonymous. One week later, 365 copies of effective questionnaires (n=365) were collected for the analysis (73% return rate). The responses ensure a balanced representation of genders (female=176; 48%, and male=189; 52%).

Table 1 summarizes the names and frequencies of students' countries of origin that participated in the study. For 365 participants, about two thirds are South Korean students (n=238), followed by students of Uzbekistan, China and other countries (n=127), 39 missing.

Table 1. The country distribution of the participants

Country	n	Country	n	Country	n	Country	n
South Korea	238	Bangladesh	11	France	4	Pakistan	1
Uzbekistan	38	Nepal	6	Indonesia	2	The Netherlands	1
China	17	Russia	5	Mongolia	2	Belgium	1

Table 2 presents the distribution of respondents by the current year of higher education and by gender variable. According to the results, the study participants have spent a certain period of time in higher education (from one to three years) and less than 10% of the participants will soon start their job hunting within few months, being senior students.

Table 2. Gender versus year of study of the participants

		Gender		Total
		Female	Male	
Year	Freshman	27	101	128
	Sophomore	64	37	101
	Junior	63	41	104
	Senior	22	10	32
Total		**176**	**189**	**365**

In the following section, the participants were given 56 sentences about robotics in general and robotics in education and were asked to state their level of agreement on a five-point Likert scale from “strongly agree” to “strongly disagree”. In ***Table 3***, these items are tabulated according to their mean scores. There are 6 items (2, 43, 44, 52, 53, 55) of negative implications in the Likert scale part, then a re-coding process is done for those questions to ensure all the items be measured in the same way. As a trend, the participants (n=365) range in between agree and disagree levels. From this interval, it can be concluded that the participants agree that the development of robotics would be an inevitable trend in the Industry 4.0 era. However, employment rate and domination concerns regarding robotics application and popularity were reflected on survey items, such as concern of replacement of machine labour for human labour (M=3.78) and concern of robotics domination over human beings (M=3.25). The least scored item (M=2.45) is about the anxiety that something bad might happen if robotics will be developed more where they tend to disagree with that statement.

Table 3. Mean scores and standard deviations on robotics and education related questions

Items	M	SD
13. Robotics will make our daily life more convenient.	3.90	0.89
15. Human labour will be replaced by robotics-related machine labour.	3.78	0.87
32. Robotics could be helpful in monitoring classroom.	3.64	0.94
23. Using robotics could create a favourable environment for innovation.	3.61	0.91
3. The world will change from “Information & Communication Technology” into “Robotics Technology” era.	3.57	0.93
7. Robotics will create an emerging market.	3.57	0.85
11. Robotics would enhance any country’s competitiveness.	3.56	0.92
17. Learning about robotics is difficult.	3.55	1.04
14. There is a demand for educational robotics.	3.53	0.84
1. The physical appearances of robots are increasingly similar to humans.	3.52	0.99
20. Students would be enthusiastic about learning how robotics are made and work.	3.52	0.91
21. Students could learn difficult knowledge more easily by repeatedly trying and practicing with robotics.	3.52	0.92
39. Robotics could complement the classroom teaching where human instructor plays the leading role, while robotics acts as an additional instructional tool.	3.50	0.88

Items	M	SD
31. Robotics could be helpful in delivering lectures.	3.49	0.93
45. Robotics would make my life more interesting.	3.48	0.95
16. In the process of learning about robotics, students should think more actively than usual.	3.47	0.89
33. Robotics could be helpful in examining students' homework.	3.47	1.02
8. Development of robotics should be a national strategy for any country.	3.45	1.00
10. Learning about robotics could increase my personal competitiveness for future career.	3.45	1.03
34. Robotics could be helpful in grading students' exams or assignments.	3.45	1.04
18. The introduction of robotics into classroom would be beneficial to increase students' learning interests.	3.44	0.96
19. The introduction of robotics into classroom would be beneficial to increase students' innovative thoughts.	3.42	0.94
5. Use of robots in education could help students apply textbook knowledge into practical knowledge.	3.41	0.96
30. Robotics could be introduced to the classroom as a supplementary instructional method.	3.41	0.85
35. The problem of insufficient number of instructors could be overcome with the help of teaching with robotics.	3.41	0.90
36. The problem of insufficient specialized instructors could be overcome with the help of teaching with robotics.	3.40	0.90
46. Robotics would make my classroom more interesting.	3.40	0.94
24. Using robotics could create a favourable environment for education.	3.37	0.95
22. Students should integrate various discipline knowledge in the process of studying robotics.	3.36	0.86
54. A student would feel happy if s/he was given a job where s/he could use robots.	3.35	0.90
4. Use of robots in education could help students develop sophisticated problem analysis skills.	3.32	0.98
37. The problem of inadequate customized education could be overcome with the help of teaching with robots.	3.32	0.89
12. Robotics should be offered as a course in higher education for all departments.	3.27	0.94
27. Robotics education could encourage students to solve problems they have encountered during their learning process.	3.26	0.97
9. Integration of robotics into education should be a national strategy for any country.	3.25	0.97
29. Robotics education could nurture students' logical thinking.	3.25	0.93
56. In the future, society would be dominated by robotics.	3.25	1.07
26. Robotics education could help improve students' self-learning ability.	3.22	1.01
6. Robots and human beings can learn from each other.	3.20	1.05
28. Robotics education could develop students' hand-making abilities.	3.18	1.06
25. Using robotics could improve students' classroom participation.	3.17	0.98
47. Robots will talk to me like a human.	3.15	1.07
42. Education with robotics should start when students are very young.	3.14	1.10
41. Robotics could satisfy students' curiosity in a classroom more than an instructor	3.11	1.04
40. Robotics could cheer up the classroom atmosphere.	3.05	1.03
51. When a student needs counselling, a robot could help.	3.04	1.06
50. Robots are trustable.	3.03	1.03
53. "Robot" as a word has no meaning to me.	3.00	1.08
49. When interacting with the robot, students could feel like they are talking to a real person.	2.92	1.09
38. Robots could have the equivalent emotions similar to human instructors.	2.88	1.14
43. Robots are scary.	2.77	1.13
48. Robots will understand human's emotions.	2.76	1.18
52. Using robotics is very complicated.	2.65	0.90
44. Robots could easily be broken while used in the classroom.	2.54	0.94
2. It scares me that robots are becoming similar to humans.	2.53	1.15
55. Something bad might happen if robots are developed more.	2.45	0.97

After the data gathering, the researchers applied the factor analysis to the entire data set, i.e., 56 items and 365 questionnaires. At first, the data were analyzed by conducting Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test and Bartlett's test of sphericity, which tests whether or not the distribution of data is adequate for conducting a factor analysis (Fraenkel et al., 2012). In the analysis, KMO coefficient was found 0.84, which is greater than 0.60 (Fraenkel et al., 2012) and the approximate X^2 (528, n=365) is equal to 3318.613, p=0.000. As the results were significant, the data were examined by an exploratory factor analysis.

Principal component analysis was implemented to data for the dimensionality of 56 items. Four significant principles were used to decide on the number of factors to rotate: a priori hypothesis measuring the unidimensionality, the Cattell scree test, the variance explained, and the factor solution interpretability. Subsequent to six rounds of rotated component matrix findings, 23 items (1, 3, 5, 10, 11, 12, 16,17, 18, 21, 22, 23, 28, 29, 30, 39, 40, 42, 45, 52, 53, 55, 56) were eliminated from the data set and rotated for six factors using a Varimax rotation, which satisfied the interpretability and total variance explained (47.58%) principles. The rotated solution and factors including eigenvalues are summarized in ***Table 4***.

Table 4. Factor analysis on robotics in general and robotics in education related questions

Item Number	**Entire Scale (α=.86)**					
	Factor 1: Emotional Robots (α=0.77)	**Factor 2: Instructional Support Robots (α=0.76)**	**Factor 3: Instructional Subordinate Robots (α=0.79)**	**Factor 4: Labor Force Robots (α=0.62)**	**Factor 5: Progressive Robots (α=0.64)**	**Factor 6: Scary Robots (α=0.67)**
48	.746					
49	.712					
38	.618					
50	.587					
51	.571					
47	.481					
41	.458					
25		.726				
26		.641				
27		.620				
24		.607				
19		.502				
46		.488				
14		.388				
33			.749			
34			.717			
32			.618			
36			.578			
35			.549			
37			.528			
31			.461			
15				.768		
13				.593		
54				.518		
20				.514		
7				.453		
8					.659	
9					.600	
6					.559	
4					.524	
43						.830
2						.739
44						.654

In addition, the researchers labelled each factor after conducting an exploratory factor analysis (EFA) based on the following criteria: understanding what each factor represents in terms of the underlying data by examining the survey items, considering the theoretical meaning that best describes the items with high loadings on each factor, consulting existing literature to identify established constructs or concepts that align with our research, prioritizing clarity while avoiding technical jargon, and ensuring the interpretability of each factor.

Finally, the entire scale analyzed for reliability (α=0.86 with 33 items) showed a pleasing level of Cronbach alpha. Besides, Cronbach (1949) is used to check each factor's reliability as well as the entire scale. Therefore, alpha values of each factor were also analyzed as shown in ***Table 4***. From the table, all factors seem to have satisfactory level of reliability.

Subsequent to factor unfolding, factor scores were determined by averaging items within each factor. Lastly, basic statistics of each factor were calculated and presented in ***Table 5***. Table 5 shows that participants have the highest mean score and least dispersion for perceptions of Factor 4, i.e., labour force robots (*M*=3.62, *SD*=0.56), which demonstrates that participants, regardless of country background, maintain labour force robots would become an irreversible trend in the job market. Moreover, the data in ***Table 5*** indicate that Factor 6, i.e., scary robots, have the lowest mean score (*M*=2.61) yet the largest standard deviation score (*SD*=0.83). This implies that participants hold relatively different views on whether the robots are scary or not. The mean score lies between disagree and no idea on a five-point Likert scale, which suggests that participants probably have relatively no fear about robots or simply think scary robots are not a big deal.

The mean score and standard deviation of Emotional robots factor is 2.99 and 0.70 respectively, which approximates 'no idea' for a five-point Likert scale. That shows participants are quite neutral on whether robots could have any emotion. Furthermore, participants demonstrated a relatively positive score for instructional support robots and instructional subordinate robots (*M*= 3.34, *SD*=0.61 and *M*= 3.45, *SD*=0.63, respectively), which implies participants are convinced and optimistic that robots could help with their studies and classroom instructions. Lastly, participants tend to agree with the progressive robots factor that the development of robots should be a national strategy for any countries with an average score of 3.31 and standard deviation of 0.69.

Table 5. Mean scores and standard deviations on factors

Factors	M	SD
Factor 1: Emotional Robots	2.99	0.70
Factor 2: Instructional Support Robots	3.34	0.61
Factor 3: Instructional Subordinate Robots	3.45	0.63
Factor 4: Labor Force Robots	3.62	0.56
Factor 5: Progressive Robots	3.31	0.69
Factor 6: Scary Robots	2.61	0.83

The differences between genders (***Table 6***) in relation to six factor items were statistically checked by independent samples t-test separately. From the analyses, three factor items significantly differed on gender variable (female and male), and for all those three factors (3, 4 and 5) male participants have higher mean scores than female participants. Male participants seem to believe more than female participants on the possibility that human labour will be replaced by machine labour and that robotics could be helpful in higher education. Besides, the male participants have a firmer belief in that the development of robotics should be promoted by countries.

Table 6. The differences between factors in relation to gender

Factor No.	Gender	*n*	*M*	*SD*	*Levene's Test for Equality of Variances*		*df*	*t*	*p*
					F	***p***			
Factor 3	Female	176	3.39	0.59	1.485	0.224	363	-1.997	0.047
	Male	189	3.51	0.65					
Factor 4	Female	176	3.52	0.58	1.504	0.221	363	-3.537	0.000
	Male	189	3.72	0.52					
Factor 5	Female	176	3.23	0.68	0.420 0.653	0.420	363	-2.067	0.039
	Male	189	3.38	0.70					

Furthermore, independent samples t-tests were performed on each of the six factor items to see whether there is a significant difference in terms of South Korean and non-South Korean participants (based on a dummy variable). Four items were found as significantly differing because of the country differences of participants (***Table 7***). From ***Table 7***, South Korean participants have higher mean score than non-South Korean participants for Factor 1 and Factor 5. It seems that South Korean participants believe more that robots could have emotions and have more trust in robots for their emotional functions. In addition, South Korean participants seem to be paradoxical on robots related machine labour and human labour. On one hand, they have a stronger concern than non-South Korean participants that robots might take place of human labour and could reduce the job opportunities. On the other hand, they also admit the robots could make life easier, convenient and robots and human being could learn from each other. However, the differences between South Korean and non-South Korean participants are not that big, so the inference might be correct or not so reliable for a statistical difference on the sample numbers.

Table 7. The differences between factors in relation to country of the participants

Factor No.	Country	*n*	*M*	*SD*	*Levene's Test for Equality of Variances*		*df*	*t*	*p*
					F	***p***			
Factor 1	S. Korea	238	3.06	0.71	0.019	0.889	363	2.680	0.008
	Non-S. Korea	127	2.85	0.67					
Factor 4	S. Korea	238	3.57	0.56	0.047	0.828	363	-2.798	0.005
	Non-S. Korea	127	3.74	0.55					
Factor 5	S. Korea	238	3.40	0.64	0.000	0.991	363	3.591	0.000
	Non-S. Korea	127	3.13	0.68					
Factor 6	S. Korea	238	2.51	0.81	0.860	0.354	363	-3.245	0.001
	Non-S. Korea	127	2.81	0.85					

Lastly, the data was controlled for the significant differences in accordance with year of study variable (from freshman to senior) using the one-way ANOVA test. Results show that there is no statistically significance based on year of study variable with respect to that factors.

5. Discussion and Conclusions

The belief that labour force robots are an irreversible trend is widespread among students. This is important as maintaining high employment rate is a macroeconomic concern for any country. It is true that labour force robots have the capacity to save more human labour from easy, repetitive and dangerous work so that human beings could focus on more sophisticated work and have more time to do work of more importance requiring more advanced skills. These findings are consistent with those of Blanas et al. (2019). This way, the society could make rapid progress in development. However, at the same time, less educated and unskilled or low-skilled employees would lose their job as some work might be done by machine robots at lower costs.

Besides the fear of human replacement by robots, the findings of this study do not reveal real fears for robots on account of them being scary, which contradict the findings of Io and Lee (2019). From the students' perspective, efficiency trumps fear when using robots in various activities. A neutral attitude was also found with respect to the emotional side of robots among the respondents. Although the extant literature highlights that the emotional nature of robots is an asset, this study does not reveal the same. It is not surprising, however, as most of the research studying the benefits of robots' emotional responses have applications in childcare or therapy (Kang et al., 2007; Chen et al., 2009).

The answers provided in the study uncover the belief that robots can help improve educational processes. Students consider that robots can both support the instructor and play the role of an instructor. The Industry 4.0 era is characterized by increasing use of robots, and students have identified several benefits of robots in education: improvement of classroom participation, improving self-learning abilities, helping to solve problems, creating a favourable environment for education, fostering innovation and making the process more interesting. These results confirm the conclusions of Campos (2017) on the robots' role to enhance creativity and on the need to include robotics in education (Hu et al., 2022) to obtain positive attitudes from students. Last, but not least, national strategies aiming at including robotics as a priority hereby confirm previous studies (Christensen, 2012).

Similar to previous studies (Dautenhahn et al., 2006; Schermerhorn et al., 2008), male and female responses differ in certain respects. On one hand, male respondents have a stronger belief that robots are likely to replace human labour in the future and that countries should focus on strategies including robotics as a priority. On the other hand, the same category of respondents seems to be more likely to acknowledge that robots in education can support the process.

It has been shown that a certain form of ethnocentricity may affect technology acceptance (Straub et al., 2002). In the same vein, the present research proves that South Korean respondents have a stronger belief that robots have an emotional side for which they trust them. However, although South Korean students are aware of the danger that humans could at some point be replaced by robots in some activities, they still hold that robots can make life easier, are convenient and mutual robot-human learning can be possible.

Practical implications. From a managerial perspective, organizations need to adopt robot utilization after careful attention has been heeded to all users. Female and non-South Korean users have to be provided with all information about the benefits of using robots, so that perception gaps be closed or at least reduced. This is mandatory so as to achieve higher efficiency in robot-supported educational processes. Technology acceptance can take time and may be uneven. Therefore, demos or pitches could be used for faster integration of technology into the educational process. In other fields of activity, managers should make sure that perceptions of robots are not distorted. Regarding robots as a menace for employees or as a factor of fear should be tactfully dealt with to make technology acceptance smoother.

Policy implications. From a policy perspective, the proliferation of robots in various industries may put pressure on the low skilled or unskilled workers, motivating them to retrain or upskill for more complex jobs or activities. Technology would, in this case, render the labour market more efficient, despite the unintended short-run job loss effect. In addition, robotics needs to be on the agenda of policymakers and included in national strategies for use in various industries. Also, given the obvious benefits reflected in the mainstream literature, robot use should be part of countries' education strategies. Although robots' integration in schools and universities may be lengthy due to cost barriers and low acceptance rate, such as strategy could help by setting intermediary deadlines.

Further Studies and Limitations. This study was conducted by exploring the perceptions of students enrolled at a South Korean university, which can be considered a research limitation. A similar study placed in a substantially different economic or cultural context could result in significantly different results. This is because South Korea is one of the leading countries in terms of robot design, production, and use. Therefore, South Koreans or those who live in South Korea may provide answers that reveal technology acceptance. Further studies could analyze this topic in less technologically or economically developed environments. Also, the perceptions of robotics use in education could also be studied among other categories of stakeholders: high-school students, parents, or teachers with regard to secondary education, on one hand, and academic staff and business managers with regard to use of robots in higher education.

Acknowledgement: This research was funded by Woosong University Academic Research in 2023.

References:

Bayram, B., & İnce, G. (2017). Advances in Robotics in the Era of Industry 4.0. In A., Ustundag & E. Cevikcan (Eds.), *Industry 4.0: Managing the Digital Transformation* (pp. 187-200). Springer International Publishing. https://doi.org/10.1007/978-3-319-57870-5_11

Blanas, S., Gancia, G., & Lee, S. Y. (2019). Who is afraid of machines? *Economic Policy, 34*(100), 627-690.

Builtin (2019). *What Is Robotics? Types of Robots* | Built In. [online] Builtin.com. Available at: https://builtin.com/robotics.

Campos, F.R. (2017). Robótica Educacional no Brasil: questões em aberto, desafios e perspectivas futuras. *Revista ibero-americana de estudos em educação, 12*(4), 2108-2121. https://doi.org/10.21723/riaee.v12.n4.out./dez.2017.8778

Cattell, R. B. (1978). *The scientific use of factor analysis in behavioral and life sciences*. New York Plenum.

Chen, G. D., & Chang, C. W. (2008). Using Humanoid Robots as Instructional Media in Elementary Language Education. In M. Eisenberg (Ed.), *2008 Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning* (pp. 201-202). IEEE. https://doi.org/10.1109/DIGITEL.2008.17

Chen, J. E., Yeh, L. T., Tseng, H. H., Wu, G. W., & Chung, I. H. (2009). Development of an Emotional Robot as a Teaching Assistant. *Learning by Playing, 5670,* 518–523. http://dx.doi.org/10.1007/978-3-642-03364-3_64

Christensen, H. (2012). Formulation of a U.S. National Strategy for Robotics [Industrial Activities]. *IEEE Robotics & Automation Magazine, 19*(2), 10-14. https://doi.org/10.1109/MRA.2012.2193931

Cureton, E. E. & D'Agostino, R. B. (1993). *Factor analysis: An applied approach*. Lawrence Erlbaum Associates.

Dautenhahn, K. Walters, M., Woods, S., Koay, K. L., Nehaniv, C. L., Sisbot, A. Alami, R. & Siméon, T. (2006). How may I serve you? A robot companion approaching a seated person in a helping context. *In Proceedings of* *the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*. Association for Computing Machinery, New York, NY, USA, 172–179. https://doi.org/10.1145/1121241.1121272

Etikan,I., Musa, S. A. & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics, 5* (1), 1-4. https://doi.org/10.11648/j.ajtas.20160501.11

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education*. New York: McGraw-Hill Humanities/Social Sciences/Languages.

Fratczak, P., Goh, Y.M., Kinnell, P., Justham, L., & Soltoggio, A. (2021). Robot apology as a post-accident trust-recovery control strategy in industrial human-robot interaction. *International Journal of Industrial Ergonomics, 82*, 103078. https://doi.org/10.1016/j.ergon.2020.103078

Gasparetto, A. (2016). Robots in History: Legends and Prototypes from Ancient Times to the Industrial Revolution. In C. Lopez Cajun & M. Ceccarelli (Eds.), *History of Mechanism and Machine Science* (pp. 39–49). Springer International Publishing. https://doi.org/10.1007/978-3-319-31184-5_5

Gasparetto, A., & Scalera, L. (2019). A Brief History of Industrial Robotics in the 20th Century. *Advances in Historical Studies*, *08*(01), 24-35, https://doi.org/10.4236/ahs.2019.81002

Gorsuch, R. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ Lawrence Erlbaum Associates.

Granulo, A., Fuchs, C., Puntoni, S. (2020). Preference for Human (vs. Robotic) Labor is Stronger in Symbolic Consumption Contexts. *Journal of Consumer Psychology, 31*(1), 72–80. https://doi.org/10.1002/jcpy.1181

Guilford, J. P. (1954). *Psychometric methods* (2nd ed.). McGraw-Hill.

Haidegger, T. (2021). Taxonomy and Standards in Robotics. In M. H. Ang, O. Khatib, & B. Siciliano (Eds.), *Encyclopedia of Robotics*. Springer Nature.

Hu, C. C., Yeh, H. C., & Chen, N. S. (2022). Teacher development in robot and IoT knowledge, skills, and attitudes with the use of the TPACK-based Support-Stimulate-Seek approach. *Interactive Learning Environments*, Early Access, 1-20. https://doi.org/10.1080/10494820.2021.2019058

Ikemoto, S., Amor, H., Minato, T., Jung, B., & Ishiguro, H. (2012). Physical Human-Robot Interaction: Mutual Learning and Adaptation. I*EEE Robotics & Automation Magazine, 19*(4), 24-35. https://doi.org/10.1109/MRA.2011.2181676

Io, H.N., & Lee, C.B. (2020). Social Media Comments about Hotel Robots. *Journal of China Tourism Research, 16*(4), 606-625. https://doi.org/10.1080/19388160.2020.1769785

Jr. Hair, J. F., Black, W. C., Babin, B. J. & Anderson, R. E. (2019). *Multivariate Data Analysis* (8th ed.). Cengage Learning EMEA.

Kang, S., Kim, J., Sohn, J., & Cho, H. (2007). Development of an experimental platform for child friendly emotional robot. In *2007 International Conference on Control, Automation and Systems, Vols. 1-6* (pp. 2792–2795). IEEE.

Li, J., Kizilcec, R., Bailenson, J., & Ju, W. (2016). Social robots and virtual agents as lecturers for video instruction. *Computers in Human Behavior, 55*, 1222-1230. https://doi.org/10.1016/j.chb.2015.04.005

McKinsey & Company. (2022, 08 17). What are Industry 4.0, the Fourth Industrial Revolution, and 4IR? *McKinsey & Company*. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir

Nyholm, L., Santamäki-Fischer, R., & Fagerström, L. (2021). Users' ambivalent sense of security with humanoid robots in healthcare. *Informatics for Health and Social Care*, *46*(2), 220-228. https://doi.org/10.1080/17538157.2021.1883027

Pearson, R. H. & Mundform, D. J. (2010). Recommended sample size for conducting exploratory factor analysis on dichotomous data. *The Journal of Modern Applied Statistical Methods, 9* (2), 359-368.

Schermerhorn, P., Scheutz, M. & Crowell, C. (2008). Robot social presence and gender: Do females view robots differently than males?. HRI 2008 - *Proceedings of the 3rd ACM/IEEE International Conference on Human-Robot Interaction: Living with Robots*. 263-270. https://doi.org/10.1145/1349822.1349857

Siciliano, B, & Khatib, O. (2016). Robotics and the Handbook. In B. Siciliano & O. Khatib (Eds.), *Springer Handbook of Robotics* (pp. 1-6). Springer-VerlagBerlin.

Sinatra, A. M., Pollard, K.A., Files, B.T., Oiknine, A.H., Ericson, M., & Khooshabeh, P. (2021). Social fidelity in virtual agents: Impacts on presence and learning. *Computers in Human Behavior, 114*, 106562. https://doi.org/10.1016/j.chb.2020.106562

Statista. (2021). *Robotics market revenue worldwide 2018-2025*. [online] Available at: https://www.statista.com/statistics/760190/worldwide-robotics-market-revenue/.

Straub, D., Loch, K. & Hill, C. (2002). Transfer of information technology to the Arab world: A test of cultural influence modeling. *Journal of Global Information Management, 9* (4), 6-28.

Sundurov, F. R., Begishev, I. R., Khisamova, Z. I., Bikeev, I. I., Latypova, E. Y., & Ishbuldin, T. R. (2021). Criminal Aspects of Robotics Applications. *Cuestiones Políticas*, *39*(68), 596-611, https://doi.org/10.46398/cuestpol.3968.38

Suzuki, K., & Kanoh, M. (2017). Investigating Effectiveness of an Expression Education Support Robot That Nods and Gives Hints. *Journal of Advanced Computational Intelligence and Intelligent Informatics*, *21*(3), 483-495. https://doi.org/10.20965/jaciii.2017.p0483

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Trevelyan, J. (1999). Redefining robotics for the new millennium. *International Journal of Robotics Research, 18* (12), 1211 - 1223. https://doi.org/10.1177%2F02783649922067816

Ursachi, G. & Zait, A. & Horodnic, I.. (2015). How reliable are measurement scales? External factors with indirect influence on reliability estimators. *Procedia Economics and Finance*, *20*, 679-686.

Wang, T., Xu, X., Wang, C., Li, Z. and Li, D. (2021). From Smart Farming towards Unmanned Farms: A New Mode of Agricultural Production. *Agriculture*, *11*(2), 145. https://doi.org/10.3390/agriculture11020145

Winkle, K., Caleb-Solly, P., Turton, A., & Bremner, P. (2019). Mutual Shaping in the Design of Socially Assistive Robots: A Case Study on Social Robots for Therapy. I*nternational Journal of Social Robotics*, *12*(4), 847-866. https://doi.org/10.1007/s12369-019-00536-9

Zhang, X. Y., Dong, P., Wang, Z. L., & Nagai, M. (2006). The Research of Interactive System of Emotional Robot Based on Multi-agent. In *2006 1st International Symposium on Systems and Control in Aerospace and Astronautics, Vols 1 and 2*. (pp.853-857). IEEE. https://doi.org/10.1109/ISSCAA.2006.1627462