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Industrial education 4.0: The role of human, technology, and data literacy

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Editorial Board

ABSTRACT

This study aims to confirm the effect of industrial education 4.0 on data, technology, and human literacy among postgraduate students in Indonesia. The research adopted covariance-based structural equation modeling by employing AMOS 25 to examine the relationship between variables. The model estimation was performed using confirmatory factor analysis as a standard model for measuring industrial education 4.0 and involved structural model analysis to confirm the hypotheses. The population in this research paper was 2.958 postgraduate students in 32 study programs, while the sample was 312 respondents, which was determined using the proportional random sampling technique. This study tested the three hypotheses proposed, showing that industrial education 4.0 has a positive and significant effect on data literacy, technological literacy, and human literacy among postgraduate students in Indonesia. This paper raises the need for developing industrial education 4.0 on these literacies.

Keywords: *data literacy, digital literacy, human literacy, industrial education 4.0.*

INTRODUCTION

The fourth industrial revolution era has been manifested by the development of science and technology, and educational institutions need to respond by providing competencies to promote new knowledge and skills (Song et al., 2021; Tay et al., 2018). Compared to the third industrial revolution, the fourth industrial revolution has new challenges, opportunities, and innovations in the field of information technology that remarkably impact socio-economic, cultural, and educational outcomes (Ivaldi et al., 2022). The fourth industrial era provides an acceleration of the industrial world, which remarkably demands a shift in mastery competence in the fields of technology, people, and data (Anggusti & Siallagan, 2020). In addition, the fourth industrial era has led to significant changes in the way businesses and organizations operate and has also created a demand for new knowledge and skills.

The fourth industrial era is shown to involve the sophistication of science and technology through its use of big data, artificial intelligence, and the Internet of Things, which can possibility to replace the human roles (Kim et al., 2017; Lima et al., 2021). The emergence of artificial intelligence as an acceleration of technology demands skills from the world of education that can displace a repetitive administrative system (Ashta & Herrmann, 2020). Accordingly, machines will potentially substitute human work, and this condition is the fulfillment of industrial efficiency and effectiveness. On the positive side, the emergence of this fourth industrial era drives new business opportunities with flexible working and promotes a more efficient and competitive product. However, the unpreparedness of human resources in terms of skills and literacy can have an impact on increasing unemployment.

Indonesia is one of the emerging countries that has been impacted by the fourth industrial era. A prior study by Muhyiddin and Nugroho (2021) reported that the unemployment rate in Indonesia had risen from 280 to 300 million people due to the acceleration of industrial technology. The data from Statistics Indonesia (BPS, 2021) documented that approximately 64 percent of Indonesia's population is of productive age, which is a potential source for facing the fourth industrial era. In doing so, higher education institutions need to provide systematic preparation of both curriculum and literacies that are required in the fourth industrial era. The World Bank reports that the job market requires multi-skilled graduates forged by education units and systems, both in secondary and higher education (WorldBank, 2019). Therefore, raising literacy among students will be beneficial in preparing them for life after graduation.

The first literacy that is fundamentally required in this era is data literacy (Fitria et al., 2019). Data literacy is linked with the skill of reading, analyzing, and using big data information in the digital world. A research study remarked that economic and scientific data are literacy skills that individuals should possess (Aoun, 2017). Data literacy is based on information technology, with the speed of analysis and connections online. Furthermore, Davenport and Patil (2012) stated that the fourth industrial revolution era involved scientific data as the basis for its development. Hence, educational institutions need to provide for prospective graduates (Deja et al., 2021; Wolff et al., 2016).

In addition to data literacy, technological literacy is definitely essential for students dealing with the fourth industrial era (Dewi et al., 2019; Fitria et al., 2019; Setiawan et al., 2020; Widayati et al., 2022). Technological literacy is shown by various skills, such as coding, artificial intelligence, and engineering principles (Aoun, 2017). Technological literacy is particularly essential because sophisticated technologies are becoming more integrated into numerous industries and sectors (Alda et al., 2020). As a consequence, individuals with a robust understanding of these technologies will be in high demand, as they will be able to help organizations leverage these technologies to improve efficiency, productivity, and innovation.

Indeed, some scholars have remarked that human literacy is an important matter for students (Fitria et al., 2019; Widayati et al., 2022). Human literacy is a vital skill for students to possess in preparation for entering the workforce. It involves being familiar with the fields of socio-cultural communication (Aoun, 2017). An earlier study also noted that high school students require human literacy (Anggresta, 2019). This is because success in the era of the industrial revolution cannot be achieved without acknowledging the importance of human social interaction. This literacy is essential for students to possess, as they enhance abilities that machines cannot replicate (Lase, 2019; Nguyen & Huynh, 2020).

Considering the matter of literacies in facing the fourth industrial era, there is little attention among scholars to involve these literacies in industrial education 4.0, which is linked with literacies. The existing studies on this theme are concerned with other literacies, such as economic literacy (e.g., Magistro, 2022; Suratno et al., 2021), financial literacy (Panos & Wilson, 2019; Suparno et al., 2022), and entrepreneurial

literacy (Chalmers et al., 2021; Kruger & Steyn, 2021). Therefore, this research specifically aims to investigate the level of data literacy, technological literacy, and human literacy among university students and confirm the impact of literacy education 4.0 on human, technological, and data literacy.

The rest of the paper is outlined as follows. Section 2 provides the theories linked with literacies and hypothesis development. Section 3 deals with the methodology adopted in this study, and Section 4 concerns the findings and discussion. The last section proposes the conclusion, limitations, and suggestions.

LITERATURE REVIEW

Literacies in the Fourth Industrial Era

The fourth industrial revolution era encourages educational institutions to prepare new students' competencies. Computerization with artificial intelligence, big data, and manufacturing businesses collaborate to shift the need for workforce skills. The industry as a company that produces goods and services requires educational institutions that are fast and ready to produce experts (Nguyen & Huynh, 2020). To produce a great generation as human capital for dealing with the fourth industrial revolution era, three things must be changed in terms of education. The first and foremost is changing the nature and mindset of students to have certain skills and literacies in dealing with the changes. Second, the important role of schools in honing and developing the talents of the next generation and preparing them after graduation. Third, it needs to develop and change learning models to adopt 21st-century learning.

In this matter, the current task of the world of education needs to incorporate into the learning process not only emphasizing strengthening old literacy competencies but also simultaneously strengthening new literacy, which is integrated into strengthening competence in scientific fields and expertise base (Choudaha & Rest, 2018). Thus, there is a need for a new reorientation in the administration of education, both in primary, secondary, and tertiary education. In order for the world of education to continue to have high relevance in the era of the fourth industrial revolution era, educators in the learning process need to integrate the learning achievements of the three fields simultaneously and in an integrated manner, namely the achievements in the fields of old literacy, new literacy, and literacy. In this fast-changing world, educators carry out classroom learning to meet demands by carrying out some learning activities as 21st-century learning.

Data literacy

In the fourth industrial era, data is essential to almost every aspect, particularly in economics and business. For example, existing data can be used to identify opportunities for new business creation (Kusumojanto et al., 2021). Additionally, data can guide students and individuals to be more efficient (Hong-Tan et al., 2021). With increasingly sophisticated technology, finding and utilizing data is becoming easier. The processed data can then become information that can be used to solve socio-economic problems (Carmi et al., 2020). Therefore, it is crucial for individuals to have data literacy. Data literacy is a fundamental stage for individuals to become proficient in using data (Gebre, 2022). Specifically, it helps individuals make data-driven decisions, interact critically with data, develop effective data governance, and make ethical data judgments (Marr, 2015).

According to Crusoe (2016), data literacy refers to the ability to understand the accuracy and use of data. Meanwhile, Aoun (2017) defined it as the ability to read digital data. These skills involve processing data into accurate information that is useful in solving problems and making decisions. Data literacy encompasses the ability to collect, understand, explain, identify, interpret, communicate, evaluate, use, analyze, and manage data, as stated by Pratama et al. (2020). Lestari and Rosana (2020) suggested that data literacy consists of four indicators: searching for data, selecting data, converting data, and maintaining or making new decisions. Based on these opinions, students must master the ability to search for and analyze data, and make decisions to be considered data literate. Additionally, possessing data literacy skills can lead to greater business opportunities and better prepare students for their future careers after graduation.

Technological literacy

The fourth industrial era revolution poses a tough challenge for educational institutions to prepare their graduate students. As mentioned previously, there is a need to have literacies, including technological literacy. According to Hasse (2017), technological literacy involves using, managing, assessing, and understanding technology. Additionally, Hardhienata et al. (2021) note that technological literacy is the ability to use technology effectively for a specific purpose. Maryland

Technology Education State Curriculum in ETS (2007) stated that technological literacy is the ability to use technology effectively in accessing, managing, integrating, evaluating, creating, and conveying information. Based on these opinions, technological literacy refers to the knowledge and skills a person possesses to use digital media and technology effectively and efficiently to search for and access information.

In this context, technological literacy refers not only to having a device and being able to access information from digital technology devices, but also to the ability to read comprehensively and write. Therefore, literacy moves beyond simply recognizing and comparing information to a higher level, including the ability to think critically by questioning, analyzing, and evaluating information, and then designing and creating new information in a suitable form or format. A previous study on this topic identified five indicators of technological literacy: accessing, managing, integrating, evaluating, and creating (ETS, 2007). Another opinion suggested that technological literacy consists of four indicators: content, process, context, and attitude (Suhendi et al., 2017). In this study, we focus on technological literacy related to how to use technology and attitudes.

Human literacy

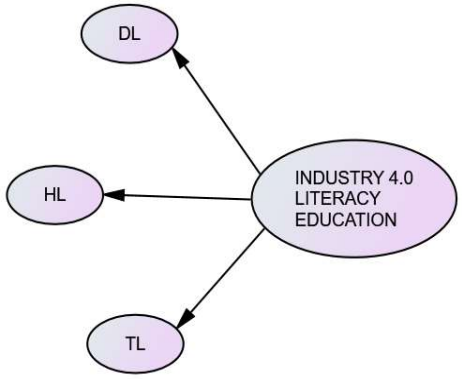
The era of the fourth industrial revolution demands a balanced society with both digital-based abilities and strong personal character developed through human literacy (Anggresta, 2019). Students must be taught human literacy to acquire abilities that cannot be performed by robots, such as empathy, leadership, and decision-making. Technology is evolving and simplifying tasks, demanding higher-level skills from individuals (Lemke, 2002). Therefore, in addition to technical abilities, students need to be educated in human aspects or general education to make them more cultured and human (Puspita, 2019). Human literacy includes communication skills, collaboration, critical thinking, and creativity, as well as competencies in leadership, cooperation, cultural development, and entrepreneurship (Anggresta, 2019).

The Human Skills Matrix (HSX) was developed by MIT to help individuals learn quickly and adapt to various industries. The matrix consists of civic and cultural literacy, organizational literacy, and digital literacy, which can be combined to develop strong thinking, interaction, leadership, and self-management abilities (Kirchain et al., 2021). The study emphasizes the importance of developing human skills in social interaction, communication, thinking skills, and creativity. As a result, the study used indicators of human literacy, such as the ability to communicate, collaborate, think critically, and be creative and innovative, as the four basic skills of human literacy. Based on theory, literature, previous studies, and the hypotheses presented in this study, the proposed research model is presented in Figure 1.

H1: There is a positive influence of literacy industrial education 4.0 towards data literacy.

H2: There is a positive influence literacy industrial education 4.0 towards human literacy.

H3: There is an influence positive literacy industrial education 4.0 towards technological literacy.



Note. DL: Data Literacy; HL: Human Literacy; TL: Technology Literacy.

Figure 1. *The proposed model of Educational literacy 4.0*

RESEARCH METHODS

Design

This research employed a quantitative method, using a self-administered survey to gather data from postgraduate students at Universitas Negeri Jakarta in Indonesia. Studying the literacies of postgraduate students can provide valuable insights that can help improve the education and training provided to them, better preparing them for their future careers as workers and entrepreneurs. This study developed a model based on theoretical studies and analysis of research thinking frameworks on the study of industrial education 4.0 for postgraduate students. The results of the model were compiled as best practices for application development.

Population, sample and data collection

The population in this study consisted of postgraduate students in the master's program and doctoral programs determined based on the criteria for the representation of the field of science as an affordable population, consisting of 32 study programs. The determination of the sample in this study was taken with an accuracy level of 95%. The sample calculation used Solvin's formula with the sampling technique of the random sampling method. Sampling was carried out randomly, regardless of the strata contained in the population (Siyoto & Sodik, 2015). The total population was 2.958, and with the sampling formula of Isaac Michael at the 5% confidence level with the total sample was 312. However, we distributed the questionnaires to more than the number of samples in order to avoid any missing or incomplete responses. In detail. the population and research samples in graduate schools for measuring industrial education literacy 4.0 are illustrated in Table 1.

Table. 1. *Population and sampling determination*

No.	Level	Study program	Number of students	Sample
1	Master	Accountancy	11	1
2		Counselling	69	7
3		Applied linguistics	39	4
4		Management	293	31
5		Environmental management	47	5
6		Education management	149	16
7		Early childhood education programs	85	9
8		Indonesian language education	51	5
9		English language education	132	14
10		Biology education	54	6
11		Basic education	125	13
12		Physical education	65	7
13		Geography education	19	2
14		Physical education	144	15
15		Chemistry education	52	5
16		Environmental education	11	1
17		Community education	0	0
18		Mathematics education	100	11
19		History education	49	5
20		Technology and vocational education	76	8
21		Educational research and evaluation	37	4
22		Education technology	79	8
23	Doctoral	Management science	282	30
24		Applied linguistics	179	19
25		Education management	148	16
26		Population and environmental pend	43	5
27		Early childhood education programs	38	4
28		Basic education	112	12
29		Physical education	204	22
30		Educational research and evaluation	75	8
31		Education technology	190	20
Total			*2958*	*312*

Instrument development

This research paper utilizes instruments adapted from Crusoe (2016) and Aoun (2017) to measure data literacy. The instruments cover searching for data, selecting data, converting data, and maintaining or making new decisions. Additionally, human literacy was estimated using instruments from Aggresta (2019), which measure communication, collaboration, thinking, and innovation. Technology literacy was calculated using instruments from Suhendi et al. (2017), which consider content, process, context, and attitude. The

instruments were translated back-to-back to ensure respondents' understanding. Furthermore, the data were validated by experts and pilot-tested with 85 respondents.

Data analysis

The data obtained were processed to determine the model using exploratory factor analysis (EFA), followed by confirmatory factor analysis (CFA), and a structural model using AMOS 25. To test the causality model between variables based on theory, the validity and reliability of construct measurement models were tested using the Cronbach score criteria of 0.6 or higher (Hair et al., 2017). Later, to estimate the goodness of fit model, several measurement criteria must be met, including a probability > 0.5 (Schermelleh-engel et al., 2003), RMSEA < 0.05 (Hu & Bentler, 1999), CFI > 0.95, and CMIN/DF values < 2 (Tabachnick & Fidell, 2007). The factor analysis test is expected to meet the CR and AVE standards with a loading factor above 0.5. Finally, the hypothesis test was carried out, and the regression coefficient and correlation tests were analyzed for normality, linearity, and significance.

RESULTS AND DISCUSSION

Demographic profile of respondents

Table 2 presents the demographic information of the respondents. The majority of respondents were postgraduate students between the ages of 26 and 30, accounting for 32.7% of the total sample. The smallest group was students under the age of 25. The next largest age group was students aged 31 to 35. Among the respondents, females accounted for 52.9% of the sample. The most common profession among postgraduate students was private employee, accounting for 28.8% of the respondents. Additionally, approximately 25% of respondents worked as government employees, followed by entrepreneurs (23.7%). In terms of education, most respondents were pursuing a master's degree (79.8%), with a focus on educational programs.

Table 2. *The demographic profile of respondents*

No./Category	Characteristic	Frequency	Percentage
1. Age	< 25 years old	102	14.4
	26 - 30 years old	45	32.7
	31 - 35 years old	50	19.2
	36 - 40 years old	45	17.6
	> 41 years old	70	16.0
2. Gender	Female	165	52.9
	Male	135	43.3
3. Occupation	Entrepreneur	74	23.7
	Teacher/Lecturer	60	19.2
	Government employees	80	25.6
	Private employees	90	28.8
	Soldier	8	2.6
4. Study program	Education	249	79.8
	Non-Educational	63	20.2
	Master/S2	178	56.4
	Doctoral/ S3	134	43.6

Data description

The data description provides a general overview of the results obtained from processing data related to the five research variables. As informed previously, the data for this study was collected by administering a questionnaire to 312 respondents. The data is grouped into three parts, which correspond to the three variables analyzed in the study that contribute to the formation of education literacy 4.0 among graduate students in higher education. The primary data obtained from the questionnaire are technology literacy (TL), data literacy (DL), and human literacy (HL). The respondents rated their level of agreement on a Likert scale with a range of 1 to 7, with 1 representing rare or low agreement and 7 representing often or high agreement (see Table 3).

Table 3. *Overview of literacies for education 4.0*

No.	Variable	Indicators	Total Items	Total Variables	Percentage
	Data Literacy				
1.	Conceptual framework	Understanding of data	1762		19.73
2.	Data collection	Identify potential data sources	1785		19.99
3.	Data management	Determining the accuracy of a data	1793	8929	20.08
		Management and processing of data	1800		20.16
4.	Data application	Use data responsibly, ethically, and legally	1789		20.04
	Human Literacy				
1.	Humanities	Care for others	3306		23.49
		Self-control	1743		12.39
2.	Communication	Leadership	1779		12.64
		Teamwork	1719	14073	12.21
		Creative & innovative	1831		13.01
3.	Design	Creative & innovative	1860		13.22
		Entrepreneurship	1835		13.04
	Technology Literacy				
1.	Understanding the basic concepts	Understand basic concepts	1815		20.29
2.	Use of technology	Use technology effectively to increase productivity	1817	8944	20.32
		Using technology to communicate and reach the outside world	1782		19.92
3.	Attitude	Ethics in using technology	1812		20.26
		Minimizing technology abuse	1718		19.21

Based on the data in Table 3, the indicator with the highest data literacy score is management and data processing, with 20.16%. On the other hand, the lowest data literacy score is in the understanding of data, with 19.73%. The highest human literacy score is in the caring for others indicator, with 23.49%. Meanwhile, the lowest human literacy score is in the self-control indicator, with only 12.39%. In technology literacy, the indicator with the lowest achievement is minimizing technology abuse, with 19.21%. The highest achievement in technological literacy is in the indicator of effectively using technology to increase productivity, with a percentage of 20.29%.

Measurement model

This study examines a model formulated based on theoretical study. However, the results obtained did not meet the Goodness of Fit Model criteria in the standardized estimate results, as shown in Figure 2. The estimation revealed that some items had a loading factor below 0.5. Therefore, these invalid items were removed from the model and re-estimated. Figure 2 shows that six instrument items were invalid, namely TL1 (0.490), TL9 (0.451), TL8 (-0.138), TL3 (0.493), HL12 (0.422), and HL14 (0.325). These items were removed from the model, and it was re-estimated. However, even after removing these invalid items, the model did not meet the GOF criteria with a p-value below 0.05. The standardized results of the estimated regression weight can be seen in Figure 3.

As the model does not meet the Goodness of Fit criteria, it needs to be improved by incorporating Covariances and M.I. Par Change inputs. After correcting and re-estimating the data, optimization of the model is carried out by utilizing suggestions from modification indices, as illustrated in Figure 4. Based on the data in Figure 4, the model now meets the criteria for the Goodness of Fit Model. A summary of the results of the standardized estimate loading factor is shown in Table 2, indicating that the instrument is valid and reliable. To assess convergent validity, we conducted AVE and composite reliability tests. The AVE values for all constructs were between 0.610 and 0.670, which confirms convergent validity. The CR values for all constructs in the measurement model ranged from 0.880 to 0.880, indicating that the composite reliability requirement was met. The detail result of validity and reliability estimation is provided in Table 4.

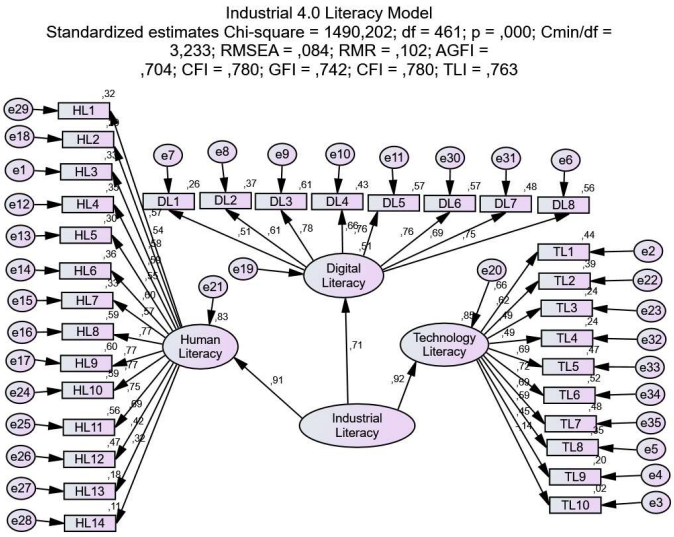


Figure 2. *Industrial Education 4.0: First model*

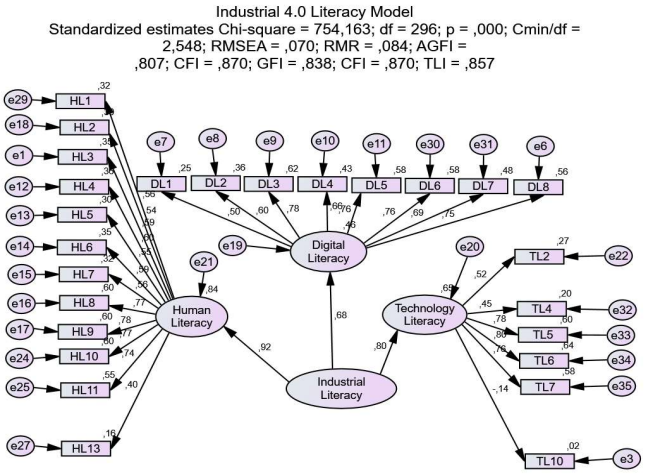


Figure 3. *Industrial Education. 4.0: Second alternative model*

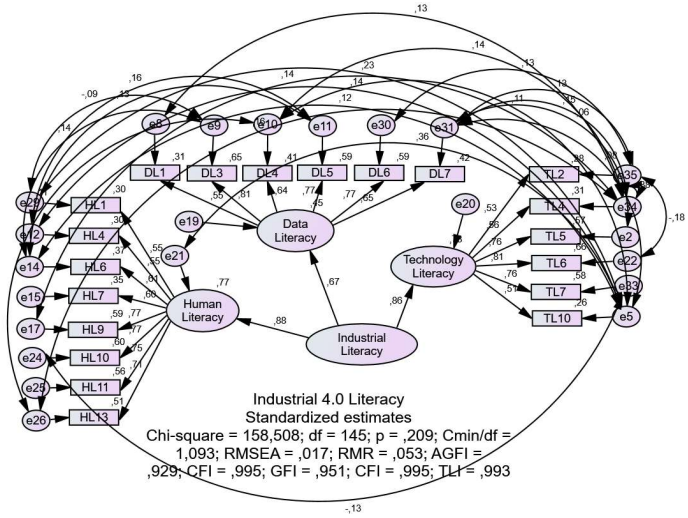


Figure 4. *Industrial Education. 4.0: GOF model*

Table 4. *Overview of Industry 4.0 Educational*

Code	Variable	λ	α	CR	AVE
DL	*Data Literacy*				
DL1	I use accurate data as a source of decision making	0.552			
DL3	Accurate and compatible primary data sources obtained online	0.809			
DL4	Before doing research, I tested the accuracy of the data with validity and reliability	0.639	0.852	0.880	0.660
DL5	The research data is tested according to the criteria of statisticians in their field	0.770			
DL6	I use statistical application software to process research data	0.770			
DL7	I use the scientific writing application for the accuracy of the citation in writing	0.647			
HL	*Human Literacy*				
HL1	I give help to people who are having difficulties	0.549			
HL4	I control the work in detail and thoroughly	0.548			
HL6	I can delegate tasks or authority at work	0.608			
HL7	I have a strong commitment when working in a team	0.595	0.860	0.870	0.610
HL9	I convey information clearly and in detail	0.766			
HL10	I can receive a directive and carry it out well	0.774			
HL11	When work has problems, I can find effective solutions	0.749			
HL13	I make a business decision and am ready to accept the risk	0.714			
TL	*Technological Literacy*				
TL2	I keep up with technology to obtain the latest information	0.526			
TL4	I learned new technology and put it into practice at work	0.559			
TL5	I use my computer, cellphone, and internet to communicate and obtain information	0.756	0.821	0.800	0.670
TL6	I pass data and information to other people online	0.815			
TL7	I provide correct information on gadgets, computers, or other devices	0.758			
TL10	I manage every electronic transaction and keep it safe	0.512			

Note: α = Cronbach's alpha; CR=composite reliability; AVE=average variance extracted

Structural model

Based on Figure 5, the estimation model is provided using an unstandardized estimate, in which shows the test of industrial education 4.0 literacy measurement model on data literacy, technological literacy, and human literacy obtained exploratory factor analysis data. The results of the complete industrial 4.0 education measurement model data processing from Amos 25 are presented in the full model standardized estimates (see Figure 5). Based on the data in Figure 5, the standardized loading estimate value is obtained and the results from the output of Amos 25 for regression weights and standardized regression weights and the influence between paths of significance (p-value) are provided in Table 5.

As informed in Table 5, this study was able to successfully test three hypotheses that demonstrated a positive and significant influence of industrial education 4.0 on data literacy, human literacy, and technological literacy among university students. These findings indicate that literacy education 4.0 has succeeded in positively and significantly improving students' data, human, and technological literacy in 21st-century learning and education. The summary of the results for the Goodness of Fit for the Industrial Education 4.0 model is presented in Table 6.

DISCUSSION AND CONCLUSION

The first hypothesis aimed to investigate the effect of Industrial Education 4.0 on data literacy. The study found that Industrial Education 4.0 has a positive and significant effect on the data literacy of university students. This means that there is a direct proportional relationship between the predictor and outcome variables. This finding confirms some preliminary studies on this relationship.

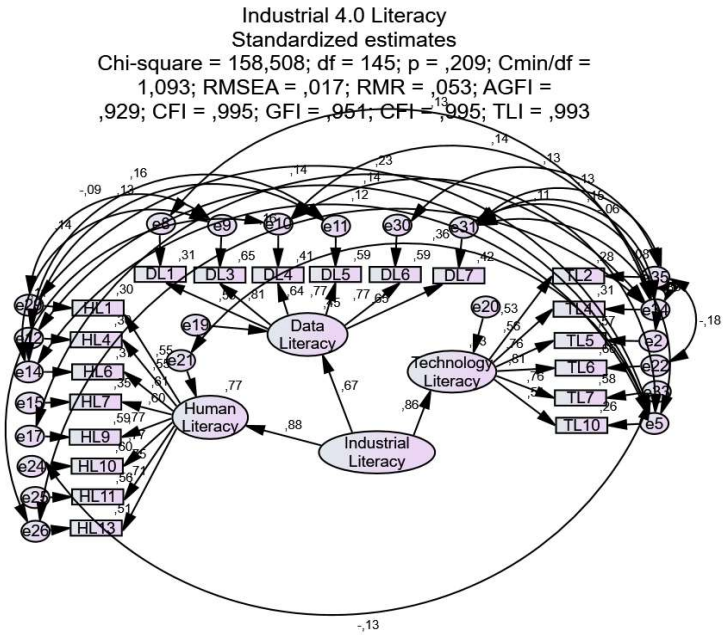


Figure 5. *Full model Industrial Education. 4.0 – Standardized estimates*

Table 5. *Hypothesis test results of industrial education measurement model 4.0*

Hypothesis Test			Estimate		S.E.	C.R.	P	Result
			RW	SRW				
Edu_Industrial 4.0	→	DL	0.669	0.432	0.054	7.942	***	Significant
Edu_Industrial 4.0	→	TL	0.855	0.441	0.049	8.955	***	Significant
Edu_Industrial 4.0	→	HL	0.880	0.573	0.063	9.038	***	Significant

Note. *** significant at level of p<0.001; DL=data literacy; TL=technological literacy; HL=human literacy; CR=composite reliability; S.E.=standard error.

Table 6. *Goodness of fit measurement model for industrial education 4.0*

Statistics	Criteria	Score	Results
Chi-square	-	158.5	-
Degree of Freedom	-	145	
p-value	> 0.05	0.209	Good Fit
CMIN/DF	< 2.00	1.093	Good Fit
Root Mean Square Residual (RMR)	< 0.05	0.053	Not Fit
Root Mean Square Error of Approximation (RMSEA)	< 0.08	0.017	Good Fit
Adjusted Goodness of Fit (AGFI)	≥ 0.90	0.929	Good Fit
Goodness of Fit Index (GFI)	≥ 0.90	0.951	Good Fit
Comparative Fit Index (CFI)	≥ 0.90	0.995	Good Fit
Tucker Lewis Index (TLI)	≥ 0.90	0.993	Good Fit

For instance, Kartika et al. (2021) stated that student data literacy is shaped by educational institutions that teach the value of nationalism through modules. Additionally, education also shapes professionalism through data literacy training (Henderson & Corry, 2021), which should be taught from an early age to develop good data literacy skills in students. This finding agrees with prior studies that emphasize the importance of data literacy in addressing the challenges of future education. Educational institutions must prepare to teach data literacy well, even if it becomes a part of the education system (Rahmita & Rosana, 2020; van Audenhove et al., 2020; Zhou, 2018).

The second hypothesis was intended to confirm the nexus between industrial education 4.0 and technology literacy among Indonesian students. The result indicated that industrial education 4.0 has a positive influence on the technology literacy of university students. This indicates that there is a direct proportional relationship between the predictor variable and the outcome variable. The basic rationale behind this finding is that industrial education 4.0 is a form of technology literacy for students. This result supports a prior study by Sari (2021), which stated that technological literacy is beneficial during the Covid-19 pandemic in student learning experiences. Indeed, Hasyim et al. (2018) stated that technological literacy in the era of digital education requires applications and that teachers who teach it require special competencies, especially in vocational schools in Indonesia, which are part of computer and information technology's 21st-century competencies and skills (Astuti et al., 2021; Sulistiyarini & Sabirin, 2020). From this finding, educational institutions need to promote technological literacy from an early age with a structured and integrated curriculum in planning, content, and implementation (Boud et al., 2016).

In addition, this study also confirmed that industrial education 4.0 has an effect on human literacy. Industrial 4.0 education is seen as a form of human literacy for students. This is because the fourth industrial era requires educational institutions to create quality and competitive human resources by strengthening personality and character through literacy (Tyas & Naibaho, 2020). Sophisticated technology must be accompanied by better human literacy, which can be taught by universities through education (Lemke, 2002). It is necessary to inculcate aspects of humanity or general education to make it more humane and cultured (Puspita, 2019). The Ministry of Research, Technology, and Higher Education in Indonesia has proclaimed human literacy as a skill that enables humans to function well in their environment and understand interactions with fellow humans.

The research results on the industrial education 4.0 model provide theoretical findings for universities in managing postgraduate schools. Therefore, educational institutions in Indonesia must implement a strategic program for promoting human literacy in 21st-century learning to complement the rapid development of science and technology. This study provides empirical input on the development of Industrial Education 4.0 at the research location, and aims to establish and improve postgraduate programs at Universitas Negeri Jakarta. The program will focus on increasing data literacy aspects such as the ability to use accurate data for decision-making, technological literacy for managing technology in electronic transactions, and maintaining security. Additionally, the program will promote human literacy in aspects of controlling work in detail and thoroughly at the postgraduate level in Universitas Negeri Jakarta, Indonesia. This research also supports the review of the global framework on core skills for living and working in the 21st century by ILO. Professional personal development in industry 4.0 requires verified skills education in society, in the form of human, digital, and technological literacy. Additionally, this research supports the Human Skills matrix (HSX) by MIT, which states that humans can adapt to industries requiring data-driven digital skills.

This study is limited by its focus solely on Universitas Negeri Jakarta. Further research can expand the geographical setting to include a wider research area. Additionally, data literacy, human literacy, and technological literacy were measured using only one dimension of measurement. Future studies can consider using alternative methods to measure these literacies. Moreover, the competencies and skills required by the business world can be developed through industrial education 4.0 in 21st-century education, which can better prepare students for the workforce.

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