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Validating a model of industrial literacy 4.0 in higher education among postgraduate students: A structural equation modeling approach

Suparno Suparno[1+]
Dedi Purwana[2]
Agus Wibowo[3]
Atia Syafa[4]

[1,2,3,4]*Universitas Negeri Jakarta, Indonesia.*
[1]*Email: suparno@feunj.ac.id*
[2]*Email: dpurwana@unj.ac.id*
[3]*Email: agus-wibowo@unj.ac.id*
[4]*Email: atia_1706622018@mhs.unj.ac.id*

(+ Corresponding author)

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ABSTRACT

This research aimed to develop a new industrial literacy model 4.0 in Higher Education. The research population consisted of 2,958 postgraduate students. Using a random sampling technique, the study obtained a sample of 312 postgraduate students. Survey data were analyzed for validity and reliability of the model, and later developed through confirmatory factor analysis (CFA) and exploratory factor analysis (EFA), using AMOS 25. The results of the model were trimmed by following the model development method to obtain goodness of fit (GOF). according to the criteria that enabled research generalizations to be carried out. The stages of the research were carried out by studying theory and literature, compiling research models, developing variable operational studies, data collection and processing, and reporting. The results of this study hinted at some best practices for developing literacy 4.0 in Higher Education in theory and measurement. The results showed that new industrial literacy 4.0 in tertiary institutions was formed by data literacy, digital literacy, and human literacy along with its constituent indicators, which met the requirements of expert validation, statistical validity and reliability, and goodness of fit. Future researchers should use the analysis of the forming factors of literacy 4.0, modeling and developing them on a wider scale in tertiary institutions, to advance educational standards and meet the megatrend of future student education skills.

Contribution/Originality: This study contributes to the integration of industrial literacy 4.0 into 21st century education in universities, regarding on how to design competence and measurement either theoretically or empirically. These findings strengthen the economic education model in tertiary institutions and create potential technology, data and humanism-based entrepreneurs.

1. INTRODUCTION

The Industrial Revolution 4.0 provides a new human direction as a study of the megatrends of this century, in economic, social, and cultural life (Duran & Sengil, 2019; Nangoy, Mursitama, Setiadi, & Pradipto, 2020; Toit, 2019), in fields of science and technology. Various changes and studies have been developed to predict how humans would live in this century because the changing environment directly demands new life skills. There have been megatrends in education (Tandon, 2020), in business, economics, and finance (Grabowska & Saniuk, 2022), in education, technology, and communication (Miranda, Navarrete, Noguez, & Ramírez-Montoya, 2021) even in

environment as revealed in the studies of world institutions (Klement, Chráska, & Chrásková, 2015), universities and government. A new era has begun, so an in-depth study is needed to provide information and measurements for future young generation, especially in the aspects of literacy that require new skills and competencies (Kuper, 2020).

Data literacy is the first fundamental literacy. The ability to utilize information sources in big data, can read, process, analyze, and even the ability to obtain accurate data based on a digital information source (Aoun, 2017). In a study by Davenport and Patil (2012), who conducted research for Harvard Business Review, found that data scientists held the most fascinating occupations in the era of Industrial Revolution 4.0. This illustrates how important data literacy is for job searching in the era of Industrial Revolution 4.0. The 21st century is full of challenges in the global era (Laar, Van Deursen, Van Dijk, & de Haan, 2020). Countries with low literacy will disappear from the world map and be colonized; they will lose their identity, national history, and even goals.

Literacy in the early days was synonymous with reading, writing, and arithmetic. Currently, literacy is our ability to read environmental conditions, the competencies needed to grow and develop, and anticipate the future towards social welfare. These competencies are now part of human pattern of life in this digital industrial era, full of innovations, and limitless creativity. The application of artificial intelligence (Sharma, 2019) with the use of machines also intend to replace human work which mainly comprises clerical and repetitive jobs, to achieve more efficiency and effectiveness.

The three previous industrial revolutions put fundamental changes and differences in developing the unique Industrial Revolution 4.0 (Anggia, Ariawan, & Pratiwi, 2020). The industrial revolution 4.0 was originally just an idea, but the German government made this idea an official idea (Roblek, Meško, & Krapež, 2016; Schwab, 2018), by showing how the use of technology made great strides in the industrial sector. Secondly, Industrial Revolution 3.0 was characterized by the use of technology in industrial activities. Far from Industrial Revolution 3.0, the current era is that of digital revolution of electronic innovation and information technology.

As a response to these digital innovations, educational institutions also need to anticipate changes in science and technology as an outcome of Industry 4.0 (Lase, 2019). Higher education is a level where students can interact with their peers and learn from their teachers. Universities teach correct thinking and educate behavior change. The ability to think and act long-term becomes a learning experience and a habit. The student's knowledge in the school environment is greatly influenced by the teacher's learning strategies in the classroom, thus the stage of student knowledge acquisition (Dwiyanti, 2017).

Concerning Indonesia, the Indonesian Internet Service Providers Association in 2018 noted that 64.8% or 171.17 million out of 264.16 million Indonesians were internet users. An increase of 10.12% from 2017 which was only 54.68% or 143.26 million of the 262 million population of Indonesia. This survey also explains that 92.6% of college students are registered as Internet users (APJII, 2018). This means that most students in Indonesia are familiar with the technology. Thus, it is very important to provide technology literacy provisions for students so they can filter the use of technology in everyday life.

Potential technologies to develop student's knowledge, skills, and experience need to be learned in schools. This is reinforced Lemke (2002) which states the importance of technology as a fundamental skill for the 21st century. The International Society for Technology in Education (ISTE) emphasized upon technology literacy requirements for students, which are implemented by the National Educational Technology Requirements (NETS). This was responded to by the Secretary Commission on Achieving Necessary Skills (SCANS) and the American Association of School Administrators, which complement the basic skills of 21st-century students with computer and technology competencies. Future life skills are in the technological era as job readiness needs for every citizen that must be fought for through education (Lemke, 2002).

One of the competencies in the technological era is the ability to understand how to develop and utilize machines and technology applications e.g., coding data, building artificial intelligence applications, and developing basic principles of industrial engineering. Recognition of technological literacy as a student competency by the

Commission on Essential Skills Achievement (SCANS) and the Association of American School Administrators states that computer and technology skills are both concepts and content in 21st-century educational competencies. Technological literacy is very important in preparing students to enter the world of work (Lemke, 2002).

The final literacy is building a knowledge about being human. Human literacy is a skill in humanities, communication, and design fields (Aoun, 2017). Students' technical skills are taught in their human dimension through human literacy (Anggresta, 2019). We need to teach Industry 4.0 to students and equip them with skills that robots do not have. Human competence is therefore one of the skills students need to prepare for the world. Having recognized the importance of industrial competence 4.0, a need was felt to study and develop a model for measuring industrial literacy 4.0 in higher education.

This study aimed to determine the validity and reliability of the proposed model of industrial literacy 4.0 in higher education. The model comprises three subconstructs, namely 1). Data literacy is structured based on the measurement dimensions of the conceptual framework, data collection, data management, and data application. 2). Human literacy is arranged based on the measurement dimensions of humanity, communication, and design, and 3). Technology literacy is structured based on the measurement dimensions of understanding basic concepts, and technology use. Such a study raised the question: Is the measurement model for the model of literacy 4.0 in higher education valid and reliable? In particular, however, this study aimed to answer the empirical and theoretical gaps as follows:

1. Empirically, to describe the level of data literacy, the level of technological literacy, and the level of human literacy in students in the Industrial Revolution Era 4.0.
2. Theoretically, to find out the literacy measurement model 4.0 of students in tertiary institutions: data literacy, technology literacy, and human literacy based on the Multi-Factor Congeneric Measurement Models.

2. LITERATURE REVIEW

2.1. Literacy 4.0

Industrial Revolution 4.0 was marked by the presence of three things: artificial intelligence, cyber systems, and manufacturing collaboration. Therefore, the era of education 4.0 requires a balance of three four competencies. The competencies needed are one of the projections of 21st-century competency needs. To produce a great generation as capital in anticipation of the industrial revolution 4.0, three things must be changed from an educational perspective; the first and most fundamental is to change the nature and mindset of today's Indonesian children. Second, the important role of schools in honing and developing the talents of the nation's next generation. The third is to develop and change learning models to be able to apply 21st-century learning.

Future global trends and challenges are urbanization, reverse brain drain, economy, and halal economy, aging society, new business models, Gen Y, big data information, technology and innovation, value-chain base, and knowledge-base (Choudaha, 2016; Choudaha & Van Rest, 2018; Intelligence, 2013). Learning as a human educational process of acquiring knowledge is very important because it shapes students' thinking abilities. We need to prepare them for learning literacy in the Industrial 4.0 era.

In the Industrial 4.0 era, various jobs have disappeared and new professional challenges have emerged. Cars do not use drivers, and statistical and financial data entry have become an application (Schwab, 2018). There will be challenges of unemployment and new professions need to be prepared by educational institutions in future. It is estimated that Indonesia's population could reach 300 million in 2035. Unemployment remains a challenge and even a threat for Indonesia, which has an unemployment rate of 5.01%. On the other hand, the majority of the working-age population is estimated to make up 64% of Indonesia's total population, and a demographic dividend is projected to occur between 2030 and 2040 (BAPPENAS, 2017). Unemployment and global competitiveness are real challenges for Indonesia. Therefore, there is a need to improve the quality of human resources, especially in the

world of work. World Bank report says the labor market needs graduates with diverse skills trained by educational units and systems at both secondary and tertiary levels (World Bank, 2019).

Education must always innovate and evaluate graduates' competencies according to the changing times. Educational forms in the industrial revolution 4.0 era, including organizational governance and human resource development (Söderström, From, Lövqvist, & Törnquist, 2012). Education with academic subjects needs to be developed contextually, with problem-based, and project-based learning. Currently, student skills are viewed as inadequate student capital to face the world of work in the era of the Industrial Revolution 4.0 (Sitepu, Eliyana, Raza, & Rosalina, 2020).

Educational institutions need to include these competencies in the curriculum of higher education institutions. Hence, modeling and measurement are needed as best practice development. On the other hand, students need to know from the start new literacy consisting of data literacy, technology literacy, and human literacy. Skills such as flexibility, adaptability, and creativity are considered essential to live and work in this rapidly changing world. To meet the above requirements, it is therefore necessary to be ahead in this Industry 4.0 era.

2.2. Human Literacy

The current era of industrial revolution 4.0 requires the community, especially students, to have digital-based capabilities so that they can balance the very fast development of science and technology. However, creating quality and competitive human resources in the world of work requires not only digital-based skills but also strengthening personality and character through human literacy (Anggresta, 2019). Human literacy needs to be taught to students to have abilities that robots cannot, such as the ability to empathize, lead, and make decisions. Experts agree that technology is growing and making simple tasks easier, which demands a person's ability to be higher as well (Lemke, 2002). This is an ability that can only be acquired by humans and not by robots. Therefore, in addition to technical abilities, students also need to be instilled with human aspects or general education so that they are more humane and cultured (Orhani, 2023).

Human literacy is the skill that enables people to function well in their environment and understand their interactions with others. There is also an opinion that human ability is the ability to be non-stiff, to reach out to people through good communication, and to master creative and innovative design. Human literacy is the ability to interact, communicate and be human in this digital age according to human nature. Based on some of these opinions, we can conclude that human literacy is about human communication skills and the humanities (how people should behave).

Communication, teamwork, critical thinking, and creativity are all tied to human literacy, or well-known as 4CS. According to a different viewpoint, human literacy entails entrepreneurship, teamwork, cultural sensitivity, and leadership (Anggresta, 2019). Based on these viewpoints, the researchers selected the Ministry of Research and Technology's indicators of human literacy: communication, collaboration, critical thinking, creativity, and innovation.

2.3. Data Literacy

Data acquisition began to gain popularity after the advent of the internet and digitization which drastically changed the way data is collected and created (Marr, 2015). The glorious era of data is also known as the digital era. Almost every day we are faced with various data and information. This is because data is believed to be necessary to produce the right decisions (Kippers, Poortman, Schildkamp, & Visscher, 2018). Having the capacity to read, analyze, and utilize knowledge (big data) in the context of technology is known as data literacy (Aoun, 2017).

Data literacy, defined by Crusoe (2016), is the capacity to comprehend what information is, how it is gathered, processed, visualized, distributed, and how it may be used effectively and efficiently. The ability to read, assess, and use knowledge (big data) in the digital age is known as data literacy, according to Aoun (2017). Based on these

opinions, it is possible to say that data literacy refers to a person's ability to use facts as knowledge to solve problems.

Data literacy contains the ability to collect data, understand it, interpret it, identify it, utilize it, convey and evaluate it, apply it, evaluate it, and manage it (Pratama, Supahar, Sari, Putri, & Adiatmah, 2020). Finding data, selecting data, converting data, and retaining or creating new decisions are reportedly the four characteristics of data literacy (Lestari & Rosana, 2020). The ability to find data, interpret data, and make judgments are signs that students need to possess to master data literacy, according to some of these opinions.

In the period of the fourth industrial revolution, data literacy influences preparation for the workforce. According to Harvard Business Review, a data scientist has the demanding job in the period known as Industry 4.0 or the 21st century. According to Aoun (2017), there is some most in-demand skills on the global market are web architecture and development framework, statistical analysis and data mining, cloud, and distributed computing, and cloud and distributed computing. According to this theory, performance is successful when competence is present and can be affected by the presence of information, skills, competence, and attitudes.

2.4. Technology Literacy

According to Hasse (2017), the International Technology Education Association (ITEA) defines technological literacy as the capacity to use, manage, evaluate, and comprehend technology. In another definition, technological literacy is the capacity to understand what technology is, how it functions, what it is used for, and how it may be used effectively and efficiently to accomplish specific goals (Lemke, 2002). Technology literacy is also the capacity to utilize technology tools appropriately and effectively to access, manage, integrate, evaluate, generate, and present information, according to the Maryland Technology Education State Curriculum in ETS (2007). Based on these perspectives, it can be said that technological literacy refers to the understanding and skills that an individual possesses to use digital media and technology to effectively find and obtain information.

Technological literacy comprises five essential elements or indicators, include: (1) accessibility—the capacity to gather and/or retrieve information; (2) management, which is the capacity to apply existing information schemes or classifications; (3) integration, which is the capacity to interpret information; and (4) evaluation, which is the capacity to assess the caliber, relevance, usefulness, or efficiency of information. (5) making—the capacity to produce knowledge through adaptation, implementation, design, creation, or writing (ETS, 2007).

Another viewpoint on evaluating technical literacy includes four indicators: (1) content, which refers to the capacity to comprehend what technology is; (2) process, which refers to the capacity to use technology; and (3) context, which refers to the capacity to apply technological principles. (4) Attitude - The capacity to adapt to changes in knowledge and technology (Suhendi, Wahidah, Linda, & Novita, 2017). Based on these viewpoints, it is determined that understanding technology, knowing how to utilize technology, and having the right attitudes towards technology are good indicators of technological literacy.

3. METHODOLOGY

This study used a quantitative method to provide the model of industrial literacies 4.0. In particular, this study developed a model that was compiled based on theoretical studies of literacy development 4.0 students. The results of the model are compiled as best practices in the application of developing literacy education in tertiary institutions. The targeted population in this study were postgraduate students in the master's and doctoral programs in Indonesia. Using basic random sampling, members of the population are chosen at randomly from the population as a whole, independent of the strata that make up the population (Guetterman, 2015; Mostafa & Ahmad, 2019); The total population was 2958, with the Isaac and Michael (1981) sampling formula at a 5% confidence level, a total sample of 312 is obtained (Ajay & Masuku, 2014; Isaac & Michael, 1981; Memon et al., 2020). Furthermore, the data were collected using instruments in 7-point of Likert scale, distributed through Google Forms.

The instruments of this study were adopted from the previous well-established studies and relevant literature. The operational definition of data literacy refers to understanding what data is, how it is gathered, processed, represented, and shared, as well as how data is used effectively and efficiently (Forum on Education Statistics, 2021; Ige, 2020; Ndukwe & Daniel, 2020; Ongena, 2023; Vista, Kim, & Care, 2018).

In this study, data literacy is provided in four dimensions: conceptual framework, data collection, data management, and data application. In addition, human literacy refers to a talent that enables people to connect, communicate, and otherwise be human in the digital age (Anggresta, 2019; Lestari & Santoso, 2019; Sari, Rejekiningsih, & Muchtarom, 2020). Human literacy is provided in three dimensions: humanities, communication, and design. Lastly, technological literacy is the capacity to understand what technology is, how it functions, what it is used for, and how it may be used effectively and efficiently to accomplish specific goals (Ali et al., 2022; Ezziane, 2007; Hassan & Akbar, 2020; Santoso, 2019).

In this study, technological literacy covers three dimensions: understanding basic concept of technology, technology use, and attitude. In more detail, the detail of instruments and measurements are presented in Table 1.

Table 1. The Instrument of the study.

Construct	Indicator	Item	Description	Source
Data literacy (DL)				
Conceptual framework	Understanding of data	DL1	I use accurate data as a source of decision making	Gummer and Mandinach (2015); Schüller (2020); Mandinach and Gummer (2016) and DePascale, Sharp, Ryan, and Betenbenner (2018)
Data collection	Searching identifies potential data sources	DL2*	To find reputable international scientific journals online, I use popular search engines such as research gate and science direct	Zweig, Irwin, Kook, and Cox (2015); Dewi, Rusilowati, and Fianti (2019) and Grillenberger and Romeike (2018)
		DL3	Accurate and compatible primary data sources obtained online	
Data management	Determine the accuracy of a data	DL4	Before doing research, I tested the accuracy of the data with validity and reliability	Ruedel, Kuchle, and Bailey (2021); DePascale et al. (2018); Grillenberger and Romeike (2018); Borghi, Abrams, Lowenberg, Simms, and Chodacki (2018); Meghana (2018); Dash, Shakyawar, Sharma, and Kaushik (2019); Darmont, Novikov, Wrembel, and Bellatreche (2022); Dhudasia, Grundmeier, and Mukhopadhyay (2023) and Kwaku Avuglah and Underwood (2019)
		DL5	The research data is tested according to the criteria of statisticians in their field	
	Management and process of data	DL6	I use statistical application software to process research data	
Data application	Use data responsibly, ethically, and legally	DL7	I use the scientific writing application for the accuracy of the citation in writing	Dewi et al. (2019); Narendra (2015); Adrian, Abdullah, Atan, and Jusoh (2018); Najafabadi et al. (2015); Rahmawati Mega, Arsisari, and Amalin Ulfah (2022) and Ramadhan, Sukma, and Indriyani (2019)
		DL8*	I use software to check for plagiarism in writing articles before sending them to journals	
Human literacy (HL)				
Humanities	Care about other people	HL1	I give help to people who are having difficulties	Pekkolay (2022); Holm, Jarrick, and Scott (2015); Reiter (2017); Schrijvers, Janssen, Fialho, and Rijlaarsdam (2019); and Dewi et al. (2019)
		HL2*	I listened to a friend when he told stories and provided solutions	
	Self-control	HL3*	I make decisions considering the consequences and responsibilities	
		HL4	I control the work in detail and thoroughly	
Communication	Leadership	HL5*	I can make timely decisions	Joynes, Rossignoli, and Amonoo-Kuofi (2019); Alkan
		HL6	I can delegate tasks or authority at	

Construct	Indicator	Item	Description	Source
			work	and Meinck (2016); Cardoso and Silva (2018); Hermann (2022); Herminingrum (2019) and Nalendra, Hermadi, and Agusta (2017)
	Teamwork	HL7	I have a strong commitment when working in a team	
		HL8*	Every work is carried out together for convenience	
	Good communication	HL9	I convey information clearly and in detail	
		HL10	I can receive a directive and carry it out well	
Design	Creative & innovative	HL11	When work has problems, I can find effective solutions	Sariwulan, Suparno, Disman, Ahman, and Suwatno (2020); Barnard and Herbst (2018); Akhter, Karim, and Islam (2022) and Mugiono et al. (2020)
		HL12*	I put into practice the new skills I got from lectures	
	Entrepreneurship	HL13	I make a business decision and am ready to accept the risk	
		HL14*	I make a business plan and carry out production analysis	
Technological literacy (TL)				
Understand basic concepts	Understand the basic concepts of technology	TL1*	I immediately went to the internet when I did not know	Ezziane (2007); DePascale et al. (2018); Ali et al. (2022); Santoso (2019) and Rahmawati Mega et al. (2022)
		TL2	I keep up with technology to get the latest information	
Technology use	Use technology effectively to increase productivity	TL3*	Online media facilitate timely work	Smith (2015); Julia and Isrokatun (2019); Wilkinson and Alshmrany (2017); Ezziane (2007); Hardinata, Suchyadi, and Wulandari (2021); Dewi et al. (2019) and Hassan and Akbar (2020)
		TL4	I learned new technology and put it into practice at work	
	Using technology to communicate and reach out to the outside world	TL5	I use my computer, cellphone, and internet to communicate and obtain information	
		TL6	I pass data and information to other people online	
Attitude	Ethics in using technology	TL7	I provide correct information on gadgets, computers, or other devices	Ventouris, Panourgia, and Hodge (2021); Martin, Shilton, and Smith (2019); Royakkers, Timmer, Kool, and Van Est (2018) and Dubov and Shoptawb (2020)
		TL8*	I use technology according to my needs and do not harm others	
	Minimizing the misuse of technology	TL9*	I protect my gadgets, computers, or other devices that i use with a password	
		TL10	I manage every electronic transaction and keep it safe	

Note: * Removed instrument items, loading factor <0.5
Source: Research data processing, 2023.

Using IBM SPSS AMOS 25 data processing software, the collected data were then analyzed to develop the model by confirmatory factor analysis (CFA) and exploratory factor analysis (EFA). The validity and reliability of construct measurement models were tested using Cronbach's criteria to validate the causality model between variables that were based on theory scores that are 0.6 or higher (Hair, Babin, & Krey, 2017). Next, a hypothesis test was performed to determine the normality, linearity, and significance of the regression coefficient and correlation. To verify the goodness of fit of the model, several requirements for measuring probability were satisfied > 0.5 (Schermelleh-Engel, Moosbrugger, & Müller, 2003), RMSEA threshold of at least 0.05 (Hu & Bentler, 1999). The criteria were approved if the values were more than 0.95 for the CFI criteria and 2 for the CMIN/DF criteria (Tabachnick & Fidell, 2013). With a loading factor exceeding 0.5, it was anticipated that the factor analysis test would meet the CR and AVE standards.

4. FINDINGS AND DISCUSSION

The demographic of respondents involved in this study is provided in Table 2. It is evident that a majority of respondents were postgraduate students aged 26 to 30 years, with a percentage of 32.7% (45), followed by students aged 31-35 years. On the other hand, the female respondents at 52.9% dominate this survey. Most of the

postgraduate student professions are private employees reaching 28.8%. Most of the respondents took master's program education with study programs in the field of education.

Table 2. The demographic profile of respondents (n=312).

No/ Category	Characteristic	Frequency	Percentage
1. Age	< 25 years old	102	14.5
	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	172	55.2
	Male	140	44.8
3. Occupation	Entrepreneur	74	23.7
	Teacher/Lecturer	60	19.3
	Government employees	80	25.6
	Private employees	90	28.8
	Soldier	8	2.6
4.Education	Education	249	79.8
	Non-educational	63	20.2
	Master/S2	178	56.4
5. Study program	Doctoral/ S3	134	43.6

Source: Research data processing, 2023.

An overview of the 4.0 literacy level of postgraduate students in Higher Education in the TL, DL, and HL measurement scales is presented in Table 3. The table shows the description of the research data. In general, variable of DL has mean (34.1), median (35), and mode (36). In addition, the variable of HL has mean (44.7), median (46), and mode (48.). Lastly, the variable of TL has mean (33.7), median (34), and mode (33), respectively.

Table 3. Description of research data.

	Variable	Mean	Median	Mode	Std. dev.	Variance	Minimum	Maximum
Descriptive statistics test/ Measurement	DL	34.1	35	36	5.1	26.1	19	42
	HL	44.7	46	48	5.8	34.2	27	56
	TL	33.7	34	33	4.3	18.9	21	42

Source: Research valid item data processing, 2023. Item $\lambda > 0.5$.

In addition, among the DL indicator variables, DL5 has the highest score with the statement *"Research data is tested according to the criteria of a statistician in their field"* with 18.9%. While the lowest indicator is of DL1 with the statement *"I use accurate data as a source of decision making"* with an achievement of 16.42%. This indicates that students at post-graduate tertiary institutions have realized the importance of research and statistical testing of data according to the criteria of statistical experts in their fields, but there is a need to increase the ability to use accurate data from both sources and processes for making appropriate and productive decisions.

The HL indicator variable that has the highest score is HL11 with the statement *"When work encounters problems, I can find effective solutions"* with an achievement of 13.22%. While the lowest indicator is HL4 with the statement *"I control the work in detail and thoroughly"*. This indicates that students in postgraduate tertiary institutions have the skills to think of solutions to work, but have a tendency to be careless, they need control in completing detailed work. Instant generations with good skills supported by environmental developments in the 21st-century era want fast jobs.

The TL indicator variable that has the highest score is TL2 with the statement *"I follow technological developments to find out the latest information"* with an achievement of 17.07%. While the lowest indicator is TL6 with the statement *"I convey data and information to other people online"*. This indicates that students in postgraduate tertiary institutions have followed technological developments and used online information as part of 21st-century literacy. However, in interactions, the tendency to convey information accompanied by data needs to be improved.

Table 4. Hypothesized three-factor CFA: Model of literacy education 4.0.

DL measurement model	HL measurement model	TL measurement model
1. $DL01 = \lambda 1\ DL + err01$	1. $HL\ 01 = \lambda 9\ \ HL + err09$	1. $TL01 = \lambda 23\ DL + err23$
2. $DL02 = \lambda 2\ DL + err02$	2. $HL\ 02 = \lambda 10\ HL + err10$	2. $TL02 = \lambda 24\ DL + err24$
3. $DL03 = \lambda 3\ DL + err03$	3. $HL\ 03 = \lambda 11\ HL + err11$	3. $TL03 = \lambda 25\ DL + err25$
4. $DL04 = \lambda 4\ DL + err04$	4. $HL\ 04 = \lambda 12\ HL + err12$	4. $TL04 = \lambda 26\ DL + err26$
5. $DL05 = \lambda 5\ DL + err05$	5. $HL\ 05 = \lambda 13\ HL + err13$	5. $TL05 = \lambda 27\ DL + err27$
6. $DL06 = \lambda 6\ DL + err06$	6. $HL\ 06 = \lambda 14\ HL + err14$	6. $TL06 = \lambda 28\ DL + err28$
7. $DL07 = \lambda 7\ DL + err07$	7. $HL\ 07 = \lambda 15\ HL + err15$	7. $TL07 = \lambda 29\ DL + err29$
8. $DL08 = \lambda 8\ DL + err08$	8. $HL\ 08 = \lambda 16\ HL + err16$	8. $TL08 = \lambda 30\ DL + err30$
	9. $HL\ 09 = \lambda 17\ HL + err17$	9. $TL09 = \lambda 31\ HL + err31$
	10. $HL\ 10 = \lambda 18\ HL + err18$	10. $TL10 = \lambda 32\ HL + err32$
	11. $HL\ 11 = \lambda 19\ HL + err19$	
	12. $HL\ 12 = \lambda 20\ HL + err20$	
	13. $HL\ 13 = \lambda 21\ HL + err21$	
	14. $HL\ 14 = \lambda 22\ HL + err22$	

Source: Researchers, 2023.

Table 4 presents the hypothesized tri-factor CFA model of literacy education 4.0, which is a three-factor structure composed of general Data Literacy (DL), Human Literacy (HL), and Technology Literacy (TL). The modeling item analysis was prepared to be measured as the following factors. Measurement of the 4.0 literacy model for postgraduate students was obtained from primary data through a survey using a semantic inferential scale questionnaire. The model is prepared based on the theoretical framework and the opinions of experts. With the help of factor analysis and a standard model, this study aims to test students' data literacy, technology literacy, and human literacy. Furthermore, to determine the measurement model, an item analysis of the constituent instruments for each variable was carried out with factor analysis (CFA) using AMOS 25 with standardized results as follows (see Figure 1.).

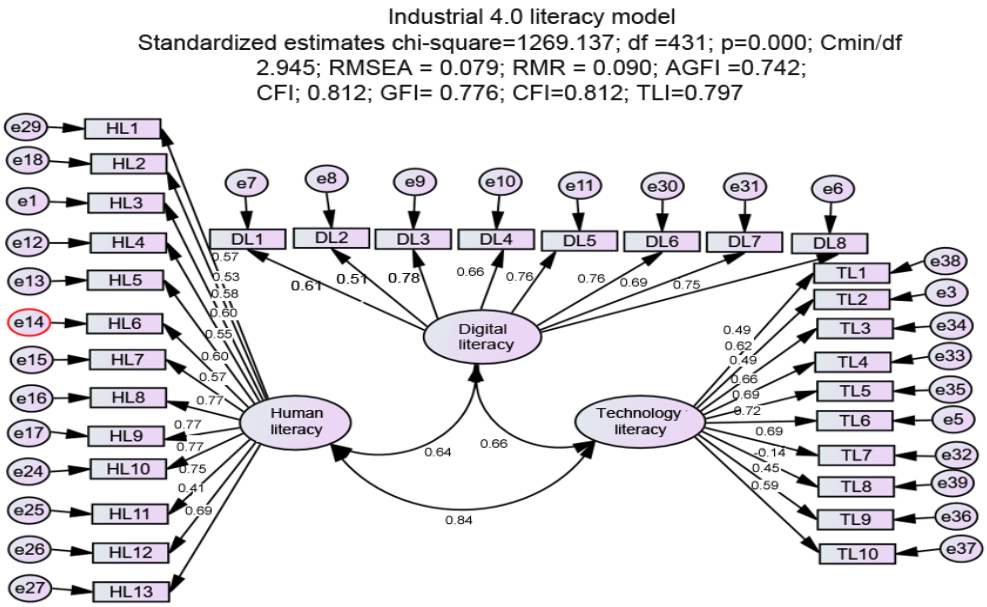

Figure 1. Industrial.4.0 standardized estimate.

Referring to the results of the total corrected item correlation analysis, information was obtained that TL on items TL1* 0.490, TL3* 0.493, TL8* -0.138, and TL9* 0.451 was declared invalid. DL on items DL2* 0.45, DL8* 0.48 declared invalid, and HL on items HL2* 0.488, HL3* 0.478, HL5* 0.44, HL8* 0.49, HL12* 0.422, HL14* 0.325 stated is not valid in measuring its latent variables, and therefore these items are excluded from the

measurement model. The loading factor (λ) value < 0.5 is invalid and is removed from the model and re-estimated. Analysis of development and measurement models with CFA for each variable instrument should not be correlated with each other. The results of the unstandardized model test are obtained with the following results:

Figure 2 illustrates the unstandardized estimate data output results with the AMOS 25 software for the industrial 4.0 model.

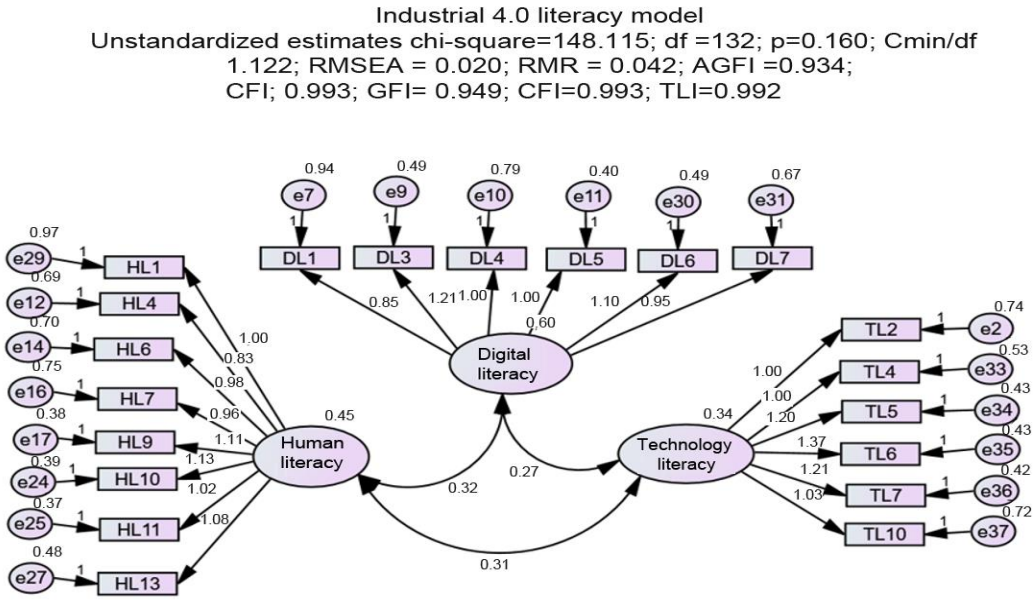

Figure 2. Industrial.4.0 unstandardized estimate.

The AMOS output data of 25 unstandardized models in the figure above shows the results of the correlation between the tested variables showing a loading factor above 0.5 and meeting the goodness of fit model criteria. The results of the standardized estimate model second order are presented in Figure 3, which illustrates the standardized estimate data output "Industry 4.0 model" meeting the goodness of fit model criteria.

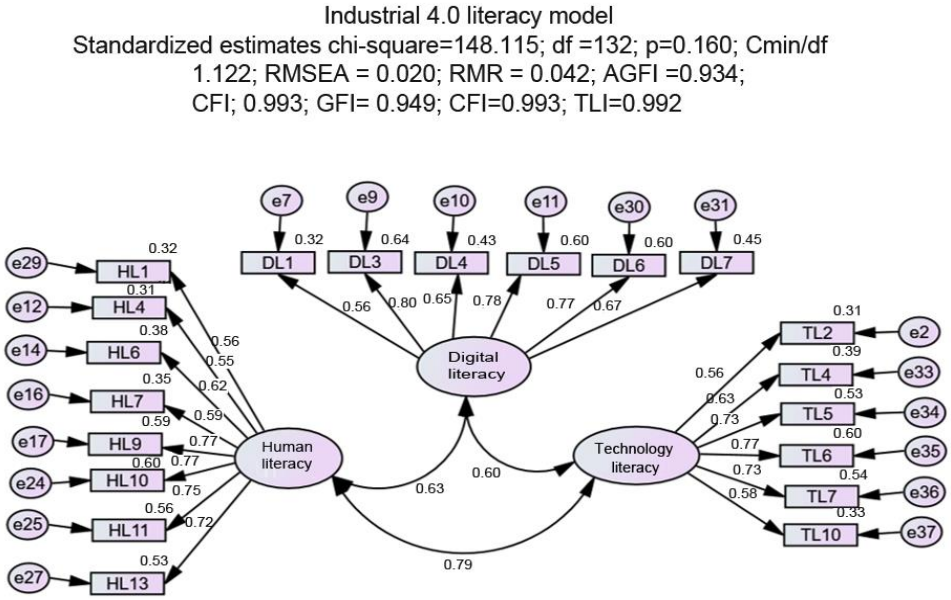

Figure 3. Industrial.4.0 standardized estimate, GOF.

The industry 4.0 model above meets the GOF Model criteria. A summary of all instrument items is presented in Table 5:

Table 5. Result of reliability and validity.

Constructs	Items	Factor loading	CR	AVE	Cronbach's alpha
DL	DL1	0.563	0.880	0.660	0.852
	DL3	0.802			
	DL4	0.655			
	DL5	0.775			
	DL6	0.772			
	DL7	0.667			
HL	HL1	0.561	0.870	0.610	0.860
	HL4	0.554			
	HL6	0.615			
	HL7	0.595			
	HL9	0.77			
	HL10	0.771			
	HL11	0.745			
	HL13	0.725			
TL	TL2	0.559	0.800	0.670	0.821
	TL4	0.627			
	TL5	0.729			
	TL6	0.772			
	TL7	0.734			
	TL10	0.577			

Note: $\lambda < 0.5$ (SD estimate), GOF model.
Source: Research data processing, 2023

After the invalid items were removed from the model, Cronbach's alpha coefficient for the three measurement models, namely TL, DL, and HL, was obtained, each greater than 0.70. This indicates that the three measurement models have an adequate level of reliability in measuring their latent variables. It can be concluded that the data obtained through the improved TL, DL, and HL measurement models are valid and reliable for use in further data analysis. That is, the DL score is a composite of the DL1, DL3, DL4, DL5, DL6, and DL7 scores. The TL score is a composite of the TL2, TL4, TL5, TL6, TL7, and TL10 scores. The HL score is a composite of the HL1, HL4, HL6, HL7, HL9, HL10, HL11, and HL13 scores, which have fulfilled the criteria for the confidence test of the accepted model DL: CR 0.880, AVE 0.660, Cronbach's Alpha 0.852. HL: CR 0.870, AVE 0.610, Cronbach's Alpha 0.860. TL: CR 0.800, AVE 0.670, Cronbach's Alpha 0.821. The average calculated score for each variable and indicator in the Industrial 4.0 Literacy model above meets the GOF criteria. A summary of all instrument items is presented in Table 6 as follows:

Table 6. Measurement model test.

Industrial 4.0 model conformity test results			
Test statistics	**Test criteria**	**Value**	**Model test results**
Chi-square	-	148.15	-
Degree of freedom	-	132	
p-value	> 0.05	0.160	Accepted
Cmin/DF	< 2.00	1.122	Accepted
Root mean square residual (RMR)	< 0.05	0.042	Accepted
Root mean square error of approximation (RMSEA)	< 0.08	0.020	Accepted
Adjusted goodness of fit (AGFI)	≥ 0.90	0.934	Accepted
The goodness of fit Index (GFI)	≥ 0.90	0.949	Accepted
Comparative fit Index (CFI)	≥ 0.90	0.993	Accepted
Tucker Lewis index (TLI)	≥ 0.90	0.992	Accepted

Source: Results of data processing by researchers, 2023.

Data analysis shows that the model instrument is valid, reliable, and meets GOF criteria and it obtained measurement results based on Chi-square criteria 148.15; Degree of Freedom 132; p-value 0.160; CMin/DF 1.122; RMR, 0.042; RMSEA 0.020; AGFI 0.934; GFI 0.949; CFI 0.993; TLI 0.992. For postgraduate students studying data literacy, technology literacy, and human literacy in 21st-century education, the aforementioned model serves as

the foundation for testing the literacy education model 4.0. The value of p > 0.05, cmin/df 2.00, RMSEA 0.08, the RMR value 0.05, and the GFI, CFI, and TLI values are all greater than 0.90, according to the findings of the goodness of fit test. This shows that, after correction, the multi-factor literacy measurement model 4.0 for Postgraduate students fits the data. To put it another way, the multi-factor literacy measurement model 4.0 used by postgraduate students can be used by the general populace. After the model was fixed, it was evident that all indicators offered a significant standardized loading estimate value (p 0.001) with a value larger than 0.50, according to objective data based on the findings of the standardized loading estimate significance test. This shows that all indicators are reliable for assessing the latent variables after the model has been fixed. According to the data, all of the AVE square root values for each construct have a higher value than the correlation value between constructs when compared to each construct's correlation value. This shows that the discriminant validity of each concept measurement model was adequate. The three measurement models, TL, DL, and HL provided a CR (construct reliability) value of more than 0.70 following the model repair. This indicates that the four measurement models have an adequate level of reliability in measuring their latent variables. It can be concluded that the data obtained through the improved literacy multi-factor measurement model 4.0 of Postgraduate students are valid and reliable for use in further data analysis.

5. CONCLUSION

This study examined the literacy model 4.0 of postgraduate students in the light of theory, prior research, and findings that have been validated through confirmatory factor analysis (CFA) and exploratory factor analysis (EFA), using AMOS 25, showing that all met the criteria for validity testing, reliability, and GOF. This study confirmed four dimensions: conceptual framework, data collection, data management, and data application, which consists of six items of measurement. In addition, human literacy covers three dimensions: humanities, communication, and design, which consists of eight valid and reliable items. Lastly, technological literacy covers three dimensions: understanding basic concept of technology, technology use, and attitude, which covers six items.

This research also supports the review of the global framework on core skills for living and working in the 21st century. Professional personal development in Industry 4.0 requires verified skills and education in society in the form of human, digital, and technological literacy. Complementing the theory of 21st-century skills development (Bidita, 2018; Spring, 2012) innovation in education (Kaur, Singh, Ongb, & Tunku, 2020; Serdyukov, 2017). Also supports the Human Skills Matrix (HSX) Massachusetts Institute of Technology, that humans can adapt to industries requiring data-driven digital skills (J-WEL, Taber, & Pagano, 2021; Muzam, 2022). For future researchers to be able to use this study of analysis of the forming factors of literacy 4.0 as modeling and developing on a wider scale and other variables related to the development of literacy 4.0 in tertiary institutions, to advance education and meet the megatrend of future student education skills.

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Institutional Review Board Statement: The Ethical Committee of the Universitas Negeri Jakarta, Indonesia has granted approval for this study on 19 October 2022 (Ref. No. 0011/unj/2022).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
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