Digital Knowledge Engineering Learning Model for Undergraduates in Thai Educational Institutions

Thamasan Suwanroj and Orawan Saeung

***Abstract*—Efficient learning management is the learning that can reflect students' identities through creating work following desirable competencies. It can develop students by providing opportunities to practice thinking about, using, and applying knowledge to real-life situations under the learning management in the digital age. The objectives of this research were to study and analyze the factors of the Digital Knowledge Engineering Learning Model: DKELM discussed by the group of experts who are all teachers from the government educational institutions in Thailand covering all undergraduate programs. The research instrument was a five-point Likert scale questionnaire about DKELM factors for undergraduates. Data were collected from 1,126 questionnaires from the sample group of 1,126 experts. The researchers used IBM SPSS Statistics 14.0 for descriptive statistical analysis and LISREL 8.72 for the second-order confirmatory factor analysis (CFA). Each aspect's content validity and reliability were .95 - .97, and each factor's content validity and reliability were .93 - .98. The research was employed by the Nakhon Si Thammarat Rajabhat University students, Nakhon Si Thammarat Province, Thailand, in 2019-2020. The discovery of the research was DKELM consisting of six knowledge-related processes gained from 18 variables: 1) Creation, 2) Storing, 3) Acquisition, 4) Access, 5) Sharing, and 6) Application. The findings are important and valuable because they can improve DKELM to develop digital and logical thinking skills for undergraduates in Thai educational institutions in the following research phase. Also, they can be used as a model to manage the learning in the digital age to emphasize and reflect the identities of each student through practical experience.**

***Index Terms*—Digital knowledge engineering, confirmatory factor analysis, educational institutions.**

I. Introduction

The educational management of Thailand in the digital age sticks to the main principle which states that every student has to gain knowledge and skills from their study. Students have to learn and develop themselves and thus, the digital literacy skills are integrated into the curriculum to develop the expected competencies [1]. The primary principal places importance on the students. Therefore, curriculum development and educational management have to support the students in developing competencies with their full potential [2], [3]. The students should be able to learn and seek new knowledge for self-development [4], [5]. Thai educational institutions specify the ways of digital learning by focusing on knowledge creation through "Digital Knowledge Engineering: DKE" to develop undergraduates' knowledge and professional skills. With the importance of the DKE, the Higher Education Commission (HEC) announced guidelines for implementation under the Thai Qualifications Framework (TQF) for Higher Education. However, these educational plans and policies have changed as the learning management of educational institutions worldwide has been ultimately moving into the digital age, models and ways of learning management have to adapt to the situation. Learning management still focuses on how students can learn and search for knowledge through the internet, as it is the most significant knowledge source in digital learning. Students in the digital age need digital technology like the DKE for work in the future [6]. They have to use digital skills to study and work together with learning in the age of open-mindedness [7], [8]. From the concepts mentioned above, the curriculum design and development, including learning and teaching management, have to develop to find new knowledge which can help the students to create, publicize, spread, and exchange the knowledge with teachers and experts in terms of the DKE [9], [10]. Thus, the first objective of this research was to study and analyze the practicality/utility of DKELM for undergraduates in Thai educational institutions. The second was to create a model focusing on the learning management to reflect the identities of each student through appropriate practice in line with the learning in the digital age.

From the literature review, the previous studies [10], [11] supported this research on the factor details and DKELM consisting of the similar six knowledge-related processes but different on the list of observed variables. This research brought the observed variables to consider and confirm. The DKE's factors were arranged based on the statistical principle from the documents and the research, but the methodology and statistics were also used to conduct the research. First, documents, literature, and related research were studied and reviewed. Next, the undergraduates' DKE model factors were created. Then they were considered and confirmed by the experts i.e. teachers from government educational institutions. The researchers analyzed the results using the DKE model's confirmatory factor analysis (CFA). This step was for considering, confirming, and arranging factors of six knowledge-related processes of the DKE according to the research and statistical principles. It was also for developing the new and concrete knowledge for the research and obtaining six knowledge-related processes of the DKELM. Compared to the previous studies [12], [13], another essential and different issue for this research is the methodology. The CFA was used in this research to create the DKELM for Thai educational institutions [14], [15]. The CFA is regarded as a high technical level and helps this research to be outstanding

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in creating new knowledge. Focusing on this research's main objectives, which were to study and analyze the factors of the DKELM, the research findings are beneficial for Thai educational institutions. They can be used as the model of learning management in educational institutions in the Thai context. They also help to properly and objectively reflect the knowledge and potential of the learners through the practice in the digital age.

II. Literature Review

The learning of DKE is the way to help the students to create, publicize and exchange their knowledge with the teachers and experts through digital technology [16]-[18]. The DKE is the learning management tool to create new knowledge. It is easy to use in learning management and practice. It works by imitating human behaviors and emphasizing the conceptual model or human knowledge in finding solutions, making decisions, and learning from knowledge management [19], [20]. The DKE uses techniques or tools to do knowledge management like the digital technology and information system to manage knowledge and the system of the digital intellectual repository. Applying the DKE process to knowledge management helps teachers and learners to reach knowledge quickly and efficiently through the internet everywhere and every time [21].

The DKE is the new information and communication technology model: ICT learning and teaching. It encourages students to study by exchanging their experiences and knowledge through digital technology. The details or definition of knowledge management provided by the experts can be summarized as follows: the learning of DKE is the way to create and seek the knowledge together with the learning process of learning by doing [22]-[24]. From the synthesis of the documents and related studies [16]-[18], the researchers concluded that there are six knowledge-related processes of the DKE learning factors:

Creation: The process to create the knowledge provided by the teachers on the issues that students are studying. It is also the process of learners' participation in creating the knowledge, which will be turned into new knowledge after the DKE learning process [16], [17], [22], [23].

Storage: The storage process sustains, improves, and examines knowledge on the issues students are studying using digital technology database management systems [16]-[18], [22]-[24].

Acquisition: The process to seek and retrieve the knowledge on the issues that students are studying. The teachers create situations; define problems or situations for the students through digital technology [17], [18], [23], [24].

Access: The process of studying the details of the contents on the issues that students are studying. The teachers observe the learning behaviors through digital technology [16], [17], [22]-[24].

Sharing: The process to transfer and exchange knowledge on the issues that students are studying. The teachers give advice and suggestions on the issues that students question and express their opinions through digital technology [16]-[18], [22]-[24].

Application: The process of examining knowledge on the issues students are studying to evaluate the learning outcomes. It tests the students' ability to apply the knowledge created from the process 1-5 to problem-solving skills and practice [16]-[18], [22]-[24].

However, if new knowledge is created after the DKEL process, that new knowledge can be brought back to recreate in process 1.

Based on the literature review of the prior study [25], showed the concrete application of digital learning in engineering through the DKE learning processes. The first process to acquire knowledge is building Creation for students using modern digital technology. Next, is Storing by using a database management system. Digital technology will be used to build Acquisition for students to build their character in solving problems or situations in engineering. The students will use Access for their learning in different situations from different sources; for example, when they have problems in engineering, they can search to find the solutions on the internet and learn from online media like Youtube. The students will learn from online media to find the solutions. When their classmates or co-workers have similar problems, the students can share their knowledge and help to solve those problems together. Sharing will happen automatically among the students on the interpersonal level. It is how students use Transfer and Sharing to solve problems. Teachers have duties to give advice and suggestions to find the solutions until the students can clear their doubts.

Moreover, students and teachers join together to give opinions and share knowledge through digital technology in the form of brief video clips. They also join to evaluate learning outcomes and summarize whether the knowledge gained from the application of the DKE learning to engineering work can be used to solve problems or not. It is in keeping with the prior study [26] that stated the model starts with Creation that will be turned into personal skills. Knowledge will be stored systematically using a database system (Storing). Individuals need to build Acquisition through situations or problem specifications. Then the teachers and students join to do the process of Access to find the solutions. It is vital to focus on building the Access of individuals and turn them into learning behavior. Improving Access skills through digital technology should be emphasized. After that, the students and teachers join to share and exchange knowledge until the students obtain Sharing Skill. Also, learning outcomes must be evaluated by both students and teachers. The DKE learning focuses on using digital technology in all processes mentioned previously. The above shows an adequate explanation of the DKELM and is helpful for its application in engineering work. The literature review mentioned above is adequate to describe the application of the DKELM covering a wide area. It shows that the DKELM has become the digital learning environment that emphasizes students' knowledge creation in engineering. It agrees with the prior research [27] that stated the DKELM is the digital learning environment focusing on students' knowledge creation through the following processes: Creation; Storing; Acquisition; Access; Sharing; and Testing on issues the students are studying.

III. METHOD

The flow chart below shows the methodology of this research.

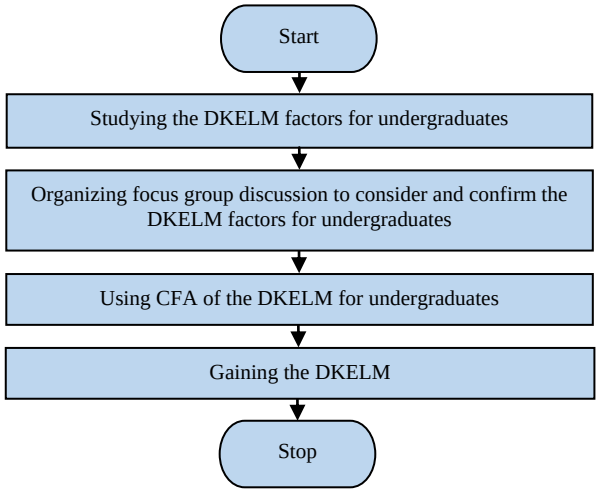


Fig. 1. The flow chart of the research methodology.

The details for each step were as follows:

A. Review Stage: The Study of DKELM Factors for Undergraduates

Source: Sources were from documents related to the DKELM for undergraduates under the conceptual framework of the DKELM factors during 2015-2019 [16]-[18]. The researchers acquired three conclusions from the documents, using the keyword "the digital knowledge engineering learning model for undergraduates." The researchers selected the contents and essential factors at least two out of three according to the concepts of searching, refining, and selecting the contents of the information to find the DKELM details for undergraduates [28], [29].

Research Instrument: The research instrument was the qualitative record form, and the steps of creating and checking the quality of the qualitative record form were as follows. First, the DKELM factors for undergraduates consisting of six knowledge-related processes were used as the conceptual framework (as mentioned above). Second, the documents and related research were studied and analyzed to find the details of the DKELM factors for undergraduates. These details were used as the guideline to create the qualitative record form. The delimitation and the issues of document analysis were defined. After that, the qualitative record form was created and presented to the first group of experts. This group was composed of 5 experts to consider, improve and approve the qualitative record form.

Data Collection: First, the researchers studied the DKELM. Then the 18 variables of the DKELM for undergraduates were presented to the same five experts to check the validity.

Data Analysis: The researchers analyzed the data obtained from the qualitative record using qualitative content analysis and descriptive analysis [17], [18]. The researchers made a table to check the frequency of the concepts relating to the DKELM details for undergraduates from all concepts studied in this research and checked the data's frequency. To consider and define the draft DKELM factors for undergraduates, the researchers evaluated the result analysis and synthesis by using the criterion in selecting the frequency at 50% [30], [31]. After that, the draft DKELM factors for undergraduates were used in the following research phase.

B. Using Focus Group Discussion to Consider the DKELM Factors for Undergraduates

Source: The source was a group of nine experts from government and private educational institutions. Purposive sampling was employed to select these nine experts in compliance with the problems and research objectives. The researchers needed experts who had expertise and knowledge in developing the DKELM for undergraduates with at least ten years of experience. Therefore, the random sampling was not suitable. These nine experts were the key informants for both parts of the research.

Research instrument: This research method was divided into parts 1 and 2; thus, the researchers created the research instrument for each part to validate the data collection and ensure its quality. The instrument used for both parts was the questionnaires to consider and confirm the details of the DKELM factors for undergraduates. Two different questionnaires were checked the content validity by the same five experts. However, the different details of creating the research instrument in each part were as follows:

Part 1: The researchers used close-ended questions consisting of 18 items with two choices for each (Yes, No). The questions included the list of DKELM for undergraduates covering six knowledge-related processes and 18 observed variables gained from the study of DKELM concepts in topic 3.1 (as mentioned above). The researchers used close-ended questions before the focus group discussion to collect the data. Five experts considered and confirmed that 18 observed variables were or were not the factors of DKELM.

Part 2: The researchers used open-ended questions relating to the list of the DKELM for undergraduates covering six knowledge-related processes and 18 observed variables confirmed from Part 1. The researchers used open-ended questions to collect the data during the focus group discussion.

Data collection: There were two parts of data collection:

Part 1: The research instrument was sent in advance to the second group of experts consisting of nine experts to ask for their opinion on considering and confirming the DKELM factor details for undergraduates. There were nine copies sent back from nine experts, 100% of the group of experts.

Part 2: The researchers analyzed the consideration results gained from the experts' opinions from part 1 to confirm the DKELM factor details for undergraduates. Then the confirmatory results were presented to the focus group discussion to acquire the essential variables of the factors. In the focus group discussion, the same nine experts also approved the DKELM factor details for undergraduates.

4) Data analysis: There were two parts as follows:

Part 1: The statistics used for data analysis were IBM SPSS 14.0 to find the frequency and percentage. The criterion used to approve the consideration and confirm the DKELM factor details for undergraduates was the experts' opinions with the answer "Yes" at least 50% [1].

Part 2: In this part, the focus group discussion of experts was held to consider and confirm the DKELM factor details for undergraduates from 18 observed variables. The open-ended questions were employed in the focus group discussion, and the experts met to consider, confirm, and rank all variables. With a unanimous resolution, the experts approved the DKELM factor details for undergraduates. The researchers analyzed the data (the experts' opinions) using typology and taxonomy techniques. The list of 18 variables approved by the unanimous resolution of the experts was the DKELM factor details for undergraduates. The statistics used for data analysis were IBM SPSS 14.0 to find the frequency and percentage.

C. Confirmatory Factor Analysis (CFA) of the DKELM for Undergraduates

Population: The population of this research consisted of 2,929 experts who are the teachers with expertise in information technology, computer technology, computer education, computer science, and computer engineering from government educational institutions across Thailand [1].

Sample: The sample group of this research consisted of 1,126 experts. For sample size determination, the researchers on the number of factors the researcher want to analyze. The proportion of the sample group must be at least ten units for one variable, and the size of the sample group needs at least 100 participants [1], [32]. This research had 18 observed variables; therefore, the minimum sample size should not consist of less than 180 people. However, for the correctness and accuracy under the statistical principle, the researchers used multi-stage sampling to determine the details of the sample group of 1,126 people. This step followed all conditions for sample size determination mentioned above.

Research instrument: The researchers used the questionnaire to ask the opinion about the DKELM factors for undergraduates in Thai educational institutions. A list of questions used in this research was created from 18 observed variables (Table I). It was a five-point Likert scale questionnaire.

5 = Want to have skills in those variables at a very high level.
4 = Want to have skills in those variables at a high level.
3 = Want to have skills in those variables at a moderate level.
2 = Want to have skills in those variables at a low level.
1 = Want to have skills in those variables at a very low level.

The content validity and the reliability for the scale of the research instrument were .95 - .97. The content validity and the reliability for factors were .93 - .98. Second-order CFA was used for data analysis. The researchers tried out the instrument with 72 experts who were not in the third group of experts to test the reliability. However, these 72 experts have expertise in information technology, and computer (as mentioned above).

Data collection: The researchers sent a letter of permission and an online questionnaire QR code to the sample group for data collection. The experts scanned the QR code to answer the questionnaire. There were 1,126 responses sent back from the sample group.

Data analysis: The researchers used descriptive statistical analysis using IBM SPSS Statistics 14.0. For the second-order CFA, LISREL 8.72 was used to analyze the factors that the researchers created the measurement model from the literature review previously mentioned. After knowing the amount of the DKELM factors for undergraduates and the experts' approval and confirmation of the 18 observed variables, it needed to use statistical methods to prove the correctness of the measurement model. At present, the CFA is very popular because of its high level of construct validity. Moreover, it can be used to correctly create new knowledge for the research.

IV. Findings

A. The Study Results of DKELM Factors for Undergraduates

This part showed the findings from studying the documents relating to the DKELM for undergraduates under the conceptual framework of the DKELM factors and from organizing the experts' focus group discussion to consider the DKELM factors for undergraduates. The research found that the DKELM factor details consisted of six knowledge-related processes, as shown in Fig. 2, and Table I which showed 18 observed variables with their research symbols.

Fig. 2. The DKELM processes for the Undergraduates of Thai educational institutions.
Remark: Fig. 2 is the input from the group of nine experts.

The results of the DKELM factors obtained from the study of related documents and the experts' consideration and analysis during the focus group discussion were brought to develop the second-order confirmatory model diagram of the DKELM essential for undergraduates in Thai educational institutions, as shown in Fig. 3.

From Fig. 3, the analysis results of the second-order CFA show that the model matches the empirical data of the essential DKELM for undergraduates in Thai educational institutions. Moreover, all goodness-of-fit statistics meet the standards.

TABLE I: THE FACTOR DETAILS, THE OBSERVED VARIABLES, AND THE SYMBOLS OF THE DKELM FOR UNDERGRADUATES

DKELM for undergraduates			
Factor	Symbol	Observed variables	Symbol
1) Creation	A	1) After the end of the learning process through digital technology, students can use computers or application programs effectively and correctly to create knowledge themselves.	A_1
		2) After the end of the learning process through digital technology, students can use computers or application programs effectively and correctly to create knowledge themselves by experimenting.	A_2
		3) After the end of the learning process through digital technology, students can use computers or application programs effectively and correctly to create knowledge themselves and solve problems by building new knowledge.	A_3
2) Storage	B	1) After the end of the learning process through digital technology, students can use computers effectively and correctly to store knowledge with application programs for building new knowledge.	B_1
		2) After the end of the learning process through digital technology, students can use computers effectively and correctly to keep the information or recorded knowledge for building new knowledge.	B_2
		3) After the end of the learning process through digital technology, students can use computers or application programs effectively and correctly to improve or examine new knowledge.	B_3
3) Acquisition	C	1) Students can use computers or application programs effectively and correctly to find knowledge on the issues they are studying after teachers create situations and define problems or situations to students through digital technology.	C_1
		2) Students can use computers or application programs effectively and correctly to browse the knowledge on the issues they are studying after teachers create situations and define problems or situations to the students through digital technology.	C_2
		3) Students can use computers or application programs effectively and correctly to apply the knowledge on the issues they are studying to real-life situations after teachers create situations and define problems or situations for the students through digital technology.	C_3
4) Access	D	1) With the teacher's observation through digital technology, students can use computers or application programs effectively and correctly to access the knowledge on the issues they are studying.	D_1
		2) With teacher's observation through digital technology, students can use computers or application programs effectively and correctly to access accurate and up-to-date knowledge by studying the content details relating to the issues they are studying.	D_2
		3) With teacher's observation through digital technology, students can use computers or application programs effectively and correctly to access the accurate and up-to-date knowledge from different sources on the internet for studying the content details relating to the issues they are studying.	D_3
5) Sharing	E	1) With the teacher's observation through digital technology, students can use computers or application programs effectively and correctly to share knowledge through the online channels or online media for presenting the content details relating to the issues they are studying.	E_1
		2) With teacher's observation through digital technology, students can use computers or application programs effectively and correctly to discuss and exchange knowledge through the online channels or online media for presenting the content details relating to the issues they are studying.	E_2
		3) With the teacher's observation through digital technology, students can use computers or application programs effectively and correctly to advise exchanging knowledge through the online channels or online media for presenting the content details relating to the issues they are studying.	E_3
6) Application	F	1) With the teacher's observation through digital technology, students can use computers or application programs effectively and correctly to examine knowledge about the issues they are studying and present the content.	F_1
		2) With the teacher's observation through digital technology, students can use computers or application programs effectively and correctly to evaluate learning outcomes of themselves and others in the issues they are studying and present the content details relating to the issues they are studying.	F_2
		3) Students can apply the knowledge created from the DKEL processes to solve problems and work effectively and correctly in real situations.	F_3
		Totals of Observed variables	18

Remark: Table I is the input from the group of nine experts.

The second-order CFA was used to confirm two issues as follows:

Issue 1: It was to confirm that the 18 observed variables were subordinate to the primary factors of six knowledge-related processes in the DKELM for undergraduates in Thai educational institutions.

Issue 2: It was to confirm that the primary factors mentioned above fit together to create the DKELM for undergraduates in Thai educational institutions. All results showed that all observed variables were subordinate to the primary factors. Also, the primary factors fit together to create the DKELM for undergraduates in Thai educational institutions according to the statistical methods.

B. Results of the CFA of the DKELM for Undergraduates

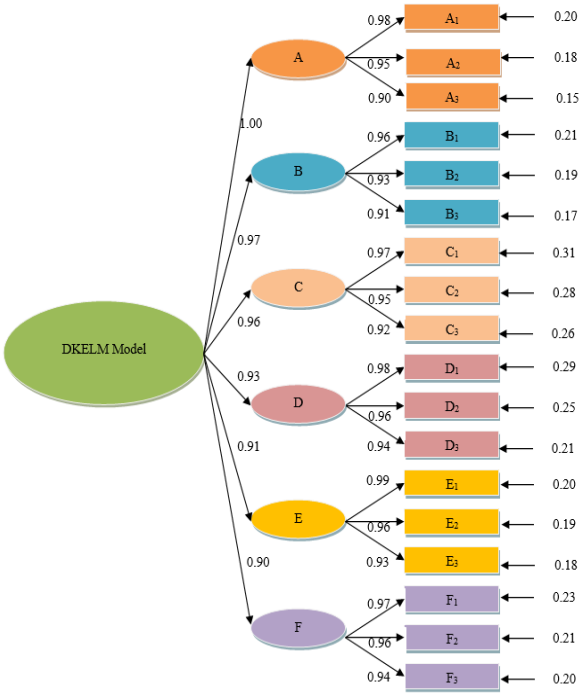
1) Goodness of fit statistics of the factor model and the empirical data are shown in Table II

TABLE II: GOODNESS OF FIT STATISTICS OF THE FACTOR MODEL AND THE EMPIRICAL DATA

Goodness of fit index	Standard [1]	Value	Result of Consideration	Conclusion
χ^2-test	p>0.05	0.65	Passed	Good
χ^2/df	<2	0.94	Passed	Good
GFI	≥0.95	1.00	Passed	Good
AGFI	≥0.95	0.99	Passed	Good
NFI	≥ 0.95	1.00	Passed	Good
CFI	≥ 0.95	1.00	Passed	Good

RMSEA	≤ 0.05	0.00	Passed	Good
SRMR	≤ 0.05	0.01	Passed	Good
RMR	≤ 0.05	0.01	Passed	Good

Remark: Table II is the input from the research sample group consisting of 1,126 experts.



Chi-Square=60.47, df=65, P-value=0.65, RMSEA=0.00

Fig. 3. The model diagram of the second-order confirmatory factor of the DKELM for the Undergraduates in Thai educational institutions.

Remark: Fig. 3 is the input from the research sample group consisting of 1,126 experts.

Table II shows that all goodness of fit statistics of the factor model and the empirical data meet the standards by considering χ^2-test which is statistically non-significant, χ^2/df = 0.94, GFI = 1.00, AGFI = 0.99, NFI = 1.00, CFI = 1.00, RMSEA = 0.00, SRMR = 0.01 and RMR = 0.01. It also shows that the model from Fig. 3 matches the empirical data of the essential DKELM for undergraduates in Thai educational institutions at a good level. Then six knowledge-related processes of the DKELM for undergraduates in Thai educational institutions are set priority in descending order. The second-order CFA results confirmed that the quantitative data collected from the sample group, and its details are shown in Table III and Fig. 4.

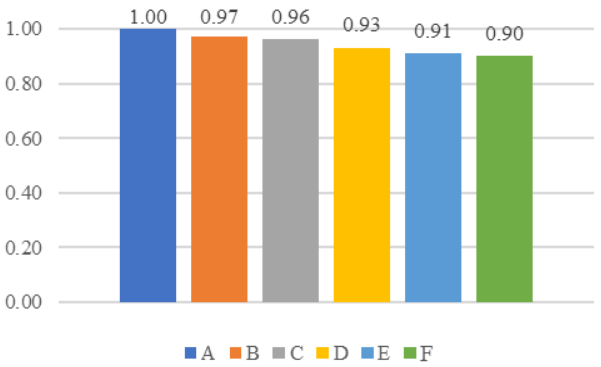
2) Factor loading, covariance, and priority of the DKELM factor for the undergraduates in Thai Educational Institutions

TABLE III: GOODNESS OF FIT STATISTICS OF THE FACTOR MODEL AND THE EMPIRICAL DATA

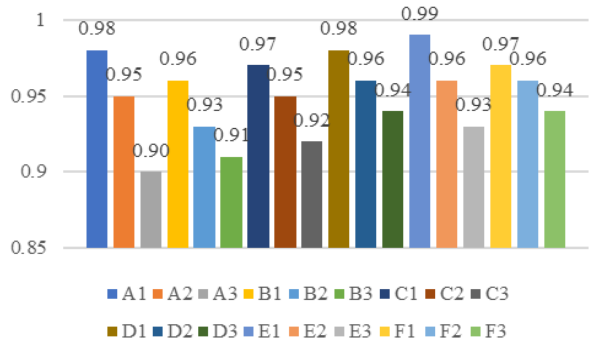
The Factors of the Learning Model		Factor loading		t	R^2	Priority of the Factor
		b	S. E.			
A		1.00	0.02	29.10*	0.97	1
	A_1	0.98	0.01	30.23*	0.96	
	A_2	0.95	0.01	29.10*	0.97	
	A_3	0.90	0.01	29.11*	0.98	
B		0.97	0.02	30.16*	0.96	2
	B_1	0.96	0.02	29.57*	0.97	
	B_2	0.93	0.03	29.71	0.85*	
	B_3	0.91	0.02	30.16	0.95	
C		0.96	0.03	28.02	0.91	3
	C_1	0.97	0.03	28.02	0.85*	
	C_2	0.95	0.02	29.21	0.90	
	C_3	0.92	0.03	28.02	0.89*	
D		0.93	0.03	31.40	0.85*	4
	D_1	0.98	0.03	30.40	0.87*	
	D_2	0.96	0.03	31.40	0.85*	
	D_3	0.94	0.03	29.14	0.83*	
E		0.91	0.03	34.41	0.88	5
	E_1	0.99	0.03	34.41	0.98	
	E_2	0.96	0.02	34.43	0.87	
	E_3	0.93	0.03	33.75	0.86	
F		0.90	0.03	32.08	0.81	6
	F_1	0.97	0.03	35.08*	0.84	
	F_2	0.96	0.02	32.15*	0.88	
	F_3	0.94	0.03	33.54	0.96	

* $p < 0.01$

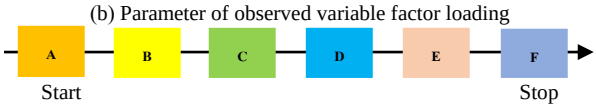
Remark: Table III is the input from the research sample group consisting of 1,126 experts.



(a) Parameter of factor loading (B)



(b) Parameter of observed variable factor loading



(c) Priority of the DKELM factor process

Fig. 4. The factor loading, parameter, and priority of DKELM factors for Undergraduates in Thai educational institutions.

Remark: Fig. 4 is the input from the research sample group consisting of 1,126 experts.

Table III and Fig. 4 show the priority in descending order of the six knowledge-related processes of the DKELM for undergraduates in Thai educational institutions by using the results of the second-order CFA to confirm the quantitative data collected from the sample group. The details of the analysis results were as follows:

First Process: Factor A- Creation A_1 was the variable

with the highest factor loading at 0.98, and the covariance of factor A- Creation was at 96%. A_2 was the variable with the second-highest factor loading at 0.95, and the covariance of factor A- Creation was at 97%. A_3 was the variable with the factor loading at 0.90, and the covariance of factor A- Creation was at 98%, respectively.

Second Process: Factor B - Storage B_1 was the variable with the highest factor loading at 0.96, and the covariance of factor B - Storage was at 97%. B_2 was the variable with the second-highest factor loading at 0.93, and the covariance of factor B - Storage was at 85%. B_3 was the variable with the factor loading at 0.91, and the covariance of factor B-Storage was at 95%, respectively.

Third Process: Factor C- Acquisition C_1 was the variable with the highest factor loading at 0.97, and the covariance of factor C- Acquisition was at 85%. C_2 was the variable with the second-highest factor loading at 0.95, and the covariance of factor C- Acquisition was at 90%. C_3 was the variable with the factor loading at 0.92, and the covariance of factor C- Acquisition was at 89%, respectively.

Forth Process: Factor D- Access D_1 was the variable with the highest factor loading at 0.98, and the covariance of factor D-Access was 87%. D_2 was the variable with the second-highest factor loading at 0.96, and the covariance of factor D-Access was at 85%. D_3 was the variable with the factor loading at 0.94, and the covariance of factor D-Access was at 83%, respectively.

Fifth Process: Factor E- Sharing E_1 was the variable with the highest factor loading at 0.99, and the covariance of factor E-Sharing was at 98%. E_2 was the variable with the second-highest factor loading at 0.96, and the covariance of factor E-Sharing was 87%. E_3 was the variable with the factor loading at 0.93, and the covariance of factor E- Sharing was at 86%, respectively.

Sixth Process: Factor F- Application F_1 was the variable with the highest factor loading at 0.97, and the covariance of factor F-Application was at 84%. F_2 was the variable with the second-highest factor loading at 0.96, and the covariance of factor F-Application was 88%. F_3 was the variable with the factor loading at 0.94, and the covariance of factor F-Application was at 96%, respectively.

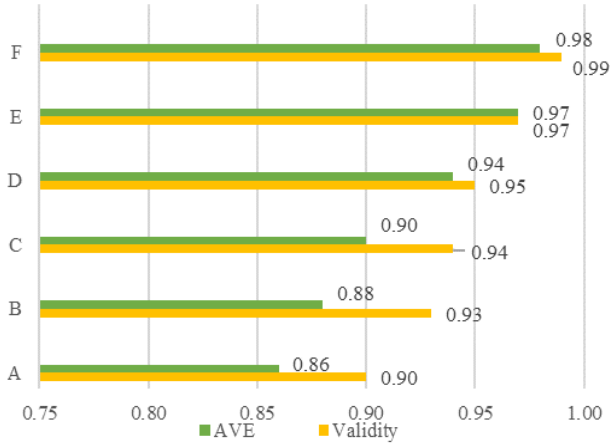
C. Factor Validity and Average Variance Extracted (AVE) of DKELM for the Undergraduates in Thai Educational Institutions

TABLE IV: FACTOR VALIDITY AND AVERAGE VARIANCE EXTRACTED (AVE) OF DKELM FOR THE UNDERGRADUATES IN THAI EDUCATIONAL INSTITUTIONS

Priority of the Factor	Validity (ρ_c)		AVE (ρ_v)	
	Value	Consideration Result	Value	Consideration Result
A	0.90	High validity	0.86	High explanation
B	0.93	High validity	0.88	High Explanation
C	0.94	High validity	0.90	High Explanation
D	0.95	High validity	0.94	High Explanation
E	0.97	High validity	0.97	High Explanation
F	0.99	High validity	0.98	High Explanation

Validity (ρ_c) = Standard >0.60, AVE (ρ_v) = Standard >0.50
Remark: Table IV is the input from the research sample group consisting of 1,126 experts.

Table IV and Fig. 5-6 show that six knowledge-related processes of the essential DKELM factors for undergraduates in Thai educational institutions have high validity (more than .60), which are in keeping with the concepts presented by [32] and [1]. The model's factors have high validity when considering the factor loading and the common factor of the observed variables from each factor's measurement of latent variables. The primary factors can also be used to explain the high variance of the variables in the factor (more than .50), which is relevant to the concepts presented by [32] and [1]. Thus the six knowledge-related processes can be considered appropriate for the DKELM for undergraduates in Thai educational institutions.



Remark: Validity (ρ_c) = Standard >0.60, AVE (ρ_v) = Standard >0.50
Fig. 5. The Factor validity and average variance extracted (AVE) of DKELM for the Undergraduates of Thai educational institutions.
Remark: Fig. 5 is the input from the research sample group consisting of 1,126 experts.

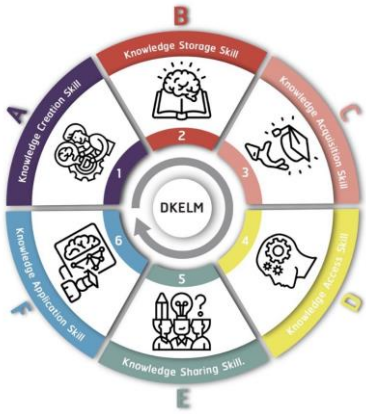


Fig. 6. The priority of the DKELM model for the undergraduates of Thai educational institutions.
Remark: Fig. 6 is the input from the research sample group consisting of 1,126 experts.

V. DISCUSSION

From the findings, there are two main issues to discuss as follows:

First issue: The study and analysis results of the DKELM factors were acquired by the experts' focus group discussion and the second-order CFA of the DKELM. It showed that 18

observed variables were the subordinates of the primary factors of six knowledge-related processes. The model matched the empirical data because all observed variables and the factors brought to analysis were acquired from the related documents and research [33], [34] and discussed in the experts' focus group discussion to consider and confirm [35]. This matching influenced all goodness of fit statistics to pass a criterion. It showed that the DKELM was practical in the context of Thai educational institutions based on the expert's point of view. The six-knowledge processes and all observed variables can be used as the DKELM for undergraduates in Thai educational institutions through curriculum development. Creating the curriculum using the DKELM will result in the most effective learning for 21st-century learners. Also, it can prepare workforce development to meet an economic model: Thailand 4.0. The findings met with the concepts [36], [37] which presented that the essential digital competencies are fundamental to the learners in creating or continuing knowledge to become the DKE. The DKE includes knowledge and skills to cover the fundamental factors under the context and needs of the learners. Furthermore, the findings are similar to the prior studies [36], [37] on the concepts, knowledge, and digital skills using the DKE processes to emphasize learners' abilities to create, publicize, expand, and exchange knowledge with teachers and experts through digital technology. The DKE processes start with defining real problems and causes. Then data are collected and analyzed. The possible causes are evaluated, the solutions are set up, and the processes are checked and evaluated. These processes are similar to the prior studies [4], [38]-[40] that analyzed to find the real reasons for the success and failure in seeking knowledge on digital media.

Second issue: The results of the second-order CFA of the DKELM were acquired from 18 observed variables and confirmed by 1,126 experts. They were relevant to the conditions of sample size determination according to the concepts [1], [31], [32], [40] presented the primary factors of the DKELM: Creation, Storage, Acquisition, Access, Sharing, and Application. For the maximum benefit to teachers and educational institutions, the primary factors of all DKELM processes must be integrated into the teaching and learning processes to improve undergraduates to become learners with knowledge creation skills in the context of the 21st-century learners. Furthermore, this is to improve undergraduates' ability to apply knowledge to real situations in professional practice and in accessing information literacy information.

VI. Contribution to Knowledge

Efficient learning management in the age of digital learning focuses on the learners' development with 21st-century skills. Learning management places importance on the following knowledge-related processes for acquiring the personal skills: Creation, Storage, Acquisition, Access, Sharing, and Application. These skills are used to test the knowledge of the issues the learners are studying. There is no difference in the human learning process no matter what contexts the learners are from Thailand, other foreign countries, or different racial groups and cultures. It can say that the DKELM for undergraduates with six knowledge-related processes previously mentioned can be applied to use as the procedure for the learners' development based on all contexts. The contents of the knowledge can be adjustable based on different contexts. Although this research studied in Thai Educational Institutions to get the DKELM for undergraduates, the researchers strongly believed that the DKELM could be applied to the national policy due to its validity in acquiring this model. Research methodology and advanced statistical principles were used to test the validity of the learning model to confirm that this model has construct validity. The mentioned DKELM is a new model developed from the research "Confirmatory Factor Analysis of the Essential Digital Competencies for Undergraduate Students in Thai Higher Education Institutions" [1], which has been widely required and applied in Thai Educational Institutions since 2019. The model has been put in the curriculum development process, learning and teaching. It indicates that essential digital competency is the first process to acquiring the mentioned learning model because it focuses on the essential procedure for developing the learners' 21st-century skills. Thus, it indicates that this learning model can be applied to all curricula no matter whether in Thailand or in foreign countries with different contexts of learning cultures. This model consists of six standard knowledge-related processes starting from Creation to the ability of Storage, followed by Acquisition which leads to Access and Sharing, and ends with Application to examine knowledge that the learners are studying. All six knowledge-related processes lead to acquiring the "skills" in keeping with the learning model. From the benefits mentioned above, this model can be brought to set the policy of learning and teaching strategies in Higher Education Institutions.

Furthermore, it can be used to focus on the learning development of the learners based on the appropriate and practical learning in the digital age. The presence of new ideas is another way of practical learning that reflects the learners' identities through work creation according to desirable competencies. This can develop students by providing opportunities to practice thinking about, using, and applying knowledge to real situations under the learning management in the digital age. DKELM model was developed from the list of 18 observed variables, which were analyzed using the second-order CFA.

The model from Fig. 3 matches the empirical data and can be used to create the DKELM for undergraduates in keeping with the empirical data.

The factors of validity and average variance extracted (AVE) of this model which can be used to create the DKELM for undergraduates of Thai educational institutions.

VII. Conclusion and Suggestion

The DKELM model developed for undergraduates in Thai educational institutions was designed to align with the empirical data. The DKELM factors for undergraduates consist of six knowledge-related processes from 18 observed variables. Each process includes 1. Creation, 2. Storage, 3.

Acquisition, 4. Access, 5. Sharing, and 6. Application. These processes are suitable for the context of undergraduates in Thai educational institutions in the age of learning management in the digital world for the following reasons. The learning and teaching in the digital age focus on bringing existing knowledge and competency to be applied creatively to develop the different types of innovation in the professional world. The innovation has to meet the needs of the society by using the DKELM, which is necessary for seeking and creating knowledge. Therefore, the educational institutions must encourage students to have those competencies instead of using the information technology pointlessly and using it with no information literacy. Moreover, they should simultaneously focus on creating the DKE and professional learning for the learners.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Thamasan Suwanroj conducted the research, analyzed the data, and wrote the paper; Orawan Saeung the research consulting; all authors had approved the final version.

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