Development of digital literacy indicators for Thai undergraduate students using mixed method research

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ABSTRACT

Digital transformation and the Internet strongly affect students' integration of technologies and their acquisition of more skills supporting their education and preparation for the workplace. This research paper developed digital literacy indicators for Thai undergraduate students using mixed method research. The purpose was to identify the actual definition, factors, and indicators of digital literacy in Thai society. The key informants were five experts in ICT, HR, and education. The second phase was to develop the measurement of digital literacy indicators using the confirmatory factor analysis (CFA) approach with a sample consisting of 1,183 undergraduate students. Data collection was conducted through a questionnaire with 54 questions. The results revealed that digital literacy criteria for Thai undergraduate students consisted of four factors containing 12 indicators. The first factor and its related operation skills consisted of cognition, invention, and presentation. The second factor was thinking skills consisting of analysis, evaluation, and creativity. The third factor was collaboration skills consisting of teamwork, networking, and sharing. The fourth factor was awareness skills consisting of ethics, law literacy, and safeguarding self. CFA was employed to test the construct validity of the research latent variables that revealed the harmony correlation of empirical data contained in this research model (chi-square $= 25.007$ with 21 degrees of freedom; $p = 0.247$; RMSEA $= 0.0127$; RMR $= 0.00658$; GFI $= 0.996$; and AGFI $= 0.987$). The weight factors of latent variables were 0.802, 0.897, 0.894, and 0.536, respectively. The value of reliability according to Cronbach's alpha coefficient of correlation was 0.644, 0.804, 0.799, and 0.288, respectively. Moreover the correlation matrix of the 12 observed variables showed correlation among latent variables with a significant level of statistic correlation at 0.01; the correlation values ranged between 0.031 and 0.612. These results were employed to develop a digital literacy test for undergraduate students to assess their skills and promote their study lives.

Introduction

The 21st century is centered on the digital economy and society. This is an extension of the development of the industrial society that expanded throughout the 20th century. Internet and digital technology provide the infrastructure of business processes and the primary communication channel in the daily lives of people. The

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number of Internet users worldwide has tripled over a ten-year period (2005–2015) from 1,024 million to 3,174 million users (The Statistics Portal, 2016). Likewise, increasing digital technology has changed the way people communicate, collaborate, create works, solve problems, make decisions, and consume information. Technology has also changed the learning paradigm for undergraduate students who must learn to harness the power of digital technologies to achieve successful study (Simpson & Obdalova, 2014; UNESCO, 2004). Present day education needs to shift from traditional teaching and learning methods based on printed materials toward digital formats. In addition, by increasing the quantity of learning resources on websites, the Internet provides a wide range of disciplines and learning opportunities. Digital literacy is a skill of the 21st century that is required for students (Leahy & Dolan, 2010).

Digital literacy has positive effects on students' skills that are essential for successful learning. Our environment is surrounded by digital technology. The enormous digital content resources are more easily accessed than traditional, paper-based resources for learning. Modern companies and organizations use computers to replace employees performing routine physical and cognitive tasks. Computers also assist employees who perform non-routine problem-solving tasks. Companies require employees to apply ICT in the work place for communication, information sharing, and simulation of business processes. Students who do not have strong digital literacy may face poor academic achievement and fewer employment opportunities. The challenge that universities face today is to embed digital literacy in the education system. Undergraduates will become workers who acquire not only knowledge, but also skills in technology to perform their jobs effectively. This paper focused on determining a digital literacy definition, applications, and performance standards for undergraduate students.

Literature Review

Digital literacy is a term popularly used today. Gilster (1997, p. 1), who initiated the term in his book "Digital Literacy", defined it as the ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers. Wilhelm (2004) suggested that a digitally literate person should be able to access, manage, integrate, evaluate, and create information. Cornell University (2009) defined it as the ability to find, evaluate, utilize, share, and create content using information technologies and the Internet. The American Library Association (2013) defined it as the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills. Digital literacy (DL) is a comprehensive concept for important skill clusters whose names are often used as synonyms, but their content is not exactly the same. Computer literacy entails a deeper understanding of digital technology and comprises both user and technical computing skills. It focuses on technical people who are computer professionals. Information literacy usually means the ability to locate, identify, retrieve,

evaluate, process, and use digital information optimally. Cyber literacy includes competence using the Internet, communication, and the Web (Karpati, 2011; Leahy & Dolan, 2010).

The competencies of digital literacy include many domains with various models. Eshet-Alakali and Amichai-Hamburger (2004) proposed a DL model that includes the ability to use digital software and hardware that includes cognitive, motoric, sociological, and emotional skills. The International Society for Technology in Education (2007) defined the digital literacy standard and indicators as creativity and innovation, communication and collaboration, research and information fluency, critical thinking/ problem solving and decision making, digital citizenship, and technology operations and concepts. Bawden (2008) described a set of DL skills that consisted of ICT skill, information literacy regarding information evaluation, media literacy, and Internet/network literacy. Calvani, Fini, and Ranieri (2009) emphasized the co-existence and integration of dimensions characterized on technological, cognitive, and ethical levels. Van Deursen and Van Dijk (2009) proposed a digital literacy model consisting of four skill groups: operational skills, formal skills, information skills, and strategic skills. The Media Awareness Network of Canada (2010) established the definition that digitally literate citizens can use, understand, and create with digital technologies. UNESCO's six basic competencies of digital literacy are accessing, managing, evaluating, integrating, creating, and communicating information. These skills need to be employed individually or collaboratively in a networked, computer-supported, and web-based environment for learning, working, or leisure (Karpati, 2011). Ferrari (2012) explained the abilities of digital literacy in seven areas: information management, collaboration, communication and sharing, creation of content and knowledge, evaluation and problem solving, and technical operations.

In Thailand, very little of the literature has discussed the definition and competencies of digital literacy. The first source was issued by The Department of Education of Thailand (2010). It provided four core digital literacy skills comprising technology, critical thinking, collaborative working, and social awareness skills. Later, a research paper by Jongsermtrakoon and Nasongkhla (2015) defined digital literacy as the ability to use digital materials including the skills to define, access, evaluate, manage, integrate, create, and communicate. More recently, a research paper by Phuapan, Viriyavejakul, and Pimdee (2016) defined six factors of digital literacy for Thai students, being the ability to access, manage, integrate, evaluate, create, and communicate. Their model consists of 19 indicators.

Research Objectives

The research aimed to study the definition of digital literacy, applications of digital literacy to develop learning quality, and the elements of digital literacy for Thai undergraduate students. An additional objective was to develop the measurement of digital literacy indicators using the confirmatory factor analysis (CFA) approach.

Methods

This research used the exploratory design for the taxonomy development model (Creswell & Plano Clark, 2011). The research design started with qualitative data to explore the phenomenon of DL for Thai undergraduates. The results of the qualitative phase were developed into a DL test and verified by the quantitative phase. The research methodology employed two phases. The first phase used a qualitative method consisting of two processes. The first process was an analysis and synthesis of digital literacy for undergraduate students by reviewing documents and research works in Thailand and from foreign countries. The output of this process led to a definition of digital literacy plus a conceptual framework for DL that applies to most of Thai society (Techataweewan & Prasertsin, 2016). The second process involved verification of the framework through interviews. The research tool for collecting data was a structured interview form evaluated by three experts for content validity of the questions. The approved interview questions earned an IOC score of 0.80—1.00 for the following questions:

1. What is your definition of digital literacy?
2. How is DL important at the present time?
3. How does DL enhance students' learning effectiveness? How can students employ DL in their academic lives?
4. Please consider the major DL factors for undergraduate students such as technological work skill, analytical thinking, collaborative working skill, and social awareness as follows:
   4.1 Which factor is the most important for students? Why?
   4.2 Which factor do you or your organization support? How?
   4.3 What are the definitions of the factors? What are the indicators for each of these factors?
   4.4 What are the strengths, weakness, and obstacles to promoting DL to students?

The researchers made appointments with five key informants for face-to-face interviews using the questions above. The informants had expertise in higher education, information technology, communication and media, and human resource management. Data collection took place in October 2015. All interview data were analyzed for content and a framework of DL was finalized for Thai undergraduate students.

The second phase of the research used a quantitative method that aimed to develop the measurement of digital literacy indicators using CFA and a sample of 1,183 undergraduate students from 14 universities in Bangkok and its vicinity, specifically 433 from public universities, 357 from Rajabhat universities, and 393 from private universities. In adherence to the principles of CFA, the number of samples followed the recommendations of Bentler and Chou (1987), who suggested 5 to 20 samples for each parameter. The standard established by Gagne and Hancock (2006) was also followed, requiring a minimum of 400 samples. Data collection was conducted through a questionnaire containing 54 questions during the first semester of the 2016 academic year.

Data collection was conducted through questionnaires. Responses to the questionnaire were organized into five levels, from most to least. The 54 questions on the questionnaire consisted of 4 latent variables. The first latent variable included 14 questions concerning operation skills (3 indicators consisting of 6 questions on cognition, 4 questions on invention; and 4 questions on presentation). The second latent variable involved 10 questions on thinking skills (3 indicators consisted of 4 questions on analysis, 3 questions on evaluation, and 3 questions on creativity). The third latent variable had 10 questions of collaboration skills (3 indicators consisting of 3 questions on teamwork; 3 questions on networking; and 4 questions on sharing). The last latent variable had 20 questions on awareness skills (3 indicators consisting of 9 questions on ethics; 7 questions on legal literacy; and 4 questions on safe guarding self). The analysis was performed through survey components analyzed on rotational axes using the SPSS for Windows software and confirmative analyses using LISREL 8.53.

Results

The content analysis of the literature review and the interviews was used to validate the framework. This resulted in three dimensions of the definition of digital literacy: how to employ DL for quality learning development, plus identification of the factors and indicators of DL for undergraduate students.

The definition of digital literacy included a set of abilities to utilize and be aware of digital information, technology and media for searching, evaluating, creating, and communicating. DL has been categorized in two levels. The basic level is defined as the utilization of digital technology for daily life such as information searching and communicating. The deeper level is defined as the cognition and utilization of digital technology for careers. Here are sample quotes from each of the interviewees that provide an overview of each perspective of DL:

"In the past there were no online databases. Nowadays there are a lot of databases and websites. Students have to have critical thinking for searching information from the Internet and using it for research and self-learning."

(personal interview, October 5, 2015)

"The present era is the Internet of everything era. Thai students have to be concerned with awareness, access, and utilization of the Internet. Broadband media are going to be digital media. We can't avoid it, therefore we must learn how to use it, create with it, and not be a slave to it."

(personal interview, October 16, 2015)

"Basic literacy level refers to reading and writing. Depth literacy means basic literacy plus its utilization in their careers, which is different for each profession such as physicians, IT, and engineers. The skills common to all of these professions must be foundational digital software

and hardware such as Microsoft Office, e-learning system, and some functions on smartphone."

(personal interview, October 19, 2015)

"Knowledge and skills of information searching, communicating, and utilizing from digital media are very important in the workplace. Presently there is increasing technology in business transactions, learning, searching, and decision making employed in many companies. Students have to prepare themselves for digital literacy skill."

(personal interview, October 20, 2015)

The adoption of digital literacy skills to improve the quality of undergraduate learning is an important issue for the digital learning environment. Digital content and learning objects are widespread among students in order to facilitate their self-directed learning. Effective learning with DL requires students to be eager to acquire knowledge, think critically, and apply existing knowledge to novel knowledge or innovation. Students also need to be able to decide what benefits creatively. Additionally, they need to use digital technologies and content with ethical awareness, avoiding conflict with others, and citing information sources in their academic work. The following quotes from the interviews provide further details on this subject:

"Digital technologies support students' multitasking ability. They can think, write, read, and listen at a PC or smartphone while doing homework… "

(personal interview, October 5, 2015)

"Digital literacy supports the ability of learning such as enthusiasm, thinking, and writing. Merely having IT ability is not sufficient to help them in learning effectively."

(personal interview, October 16, 2015)

"Nowadays education has shifted to global learning. Many courses are provided online and are linked together. Students can study in any university in the world. Don't worry about digital usage; rather, be concerned with application and creativity. DL is an important skill for the 21 century."

(personal interview, October 20, 2015)

The digital literacy factors and indicators for Thai undergraduate students were synthesized from documents and interviews. The results revealed four factors comprising operation skills, thinking skills, collaboration skills, and awareness skills which consist of 12 indicators (Figure 1) as explained below.

Operation skills consist of three indicators: cognition, invention, and presentation. The first indicator is cognition, which refers to knowledge and understanding concerning ICT and digital media. It includes the selection and discriminating use of technology in various situations and appropriate ways. The invention indicator refers to the ability to integrate and apply ICT and digital media to invent work, create knowledge, or make innovations. The presentation indicator is the ability to present digital content in various formats such as selection of an appropriate format for a giving target audience and for receiving effective feedback.

Thinking skills consist of analysis, evaluation, and creativity. Analysis is the ability of consideration, digestion, interpretation, and finding relations of content in digital information. This includes organizing content in formats such as sorting, classifying, or calculating, for summarizing or other specific purposes. Evaluation is the ability of assessing information in terms of necessity, utilization, accuracy, timeliness, and reliability, in addition to discriminating misinformation, propaganda, and hate speech. Creativity involves the ability of problem solving, answering diversely, flexibility, and positive thinking applied to novel inventions and knowledge for the public interest.

Collaboration skills consist of three indicators, namely, teamwork, networking, and sharing. Teamwork is the ability to use ICT and digital media in collaboration with others either as the leader or a member of a team. This includes the full use of the potential for working together and achieving the group goals. The networking indicator is the ability to create or subscribe to online network groups for building relationships for mutual benefit. Sharing is an ability to exchange information through ICT in digital format and through proper channels with concern for the value and usefulness to recipients.

Awareness skills comprise three indicators: ethics, legal literacy, and safeguarding self. Ethics refer to practices that are accepted by society in general or on the basis of doctrine. This includes the netiquette of respecting diversity and inequalities of social groups in digital technology communications. Legal literacy is the knowledge, understanding, and compliance with the laws and regulations relating to the use and access of information technology and digital media. Safeguarding self is the ability to manage personal data by recognizing the risks inherent on the Internet.

The following quotes from the interviews provide further details on this subject:

"Students must have general ICT skills concerning hardware, software and servers. They need to know how to create websites using basic HTML or Dreamweaver, use Adobe Photoshop for graphic works, and use MS Office. They also can connect to the Internet, test the speed, and download software."

"Skills for digital literacy are information literacy skill regarding information use and evaluation, critical thinking skill regarding understanding and creating, and collaboration skills for creating networks."

(personal interview, October 5, 2015)

"Due to the large amount of data on the web, communication requires analysis and evaluation for accuracy and reliability of information. Students must not simply cut and paste. They should be aware of plagiarism, ethics, and fake websites."

"Digital literacy isn't divided into hardware or software. It integrates every ICT skill as one function, just as on smartphone. In addition to the ICT skill, students must be able to perceive computer malpractice law, copyright law, and privacy law in their study and work lives."

(personal interview, October 16, 2015)
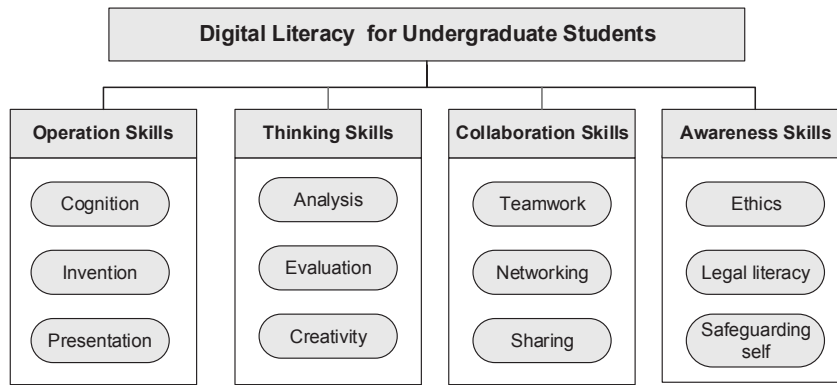
Figure 1 Factors and indicators of digital literacy for undergraduate students

"In the employer's view, graduates must have IT skills including at least Word Excel, and PowerPoint. But the more important point is that they can work well together in a team."

(personal interview, October 19, 2015)

"Invention and creative skills are necessary for digitally literate students. Basically, they can upload clips to the public through YouTube, make graphic works, edit photos or clips, and present works with digital media."

(personal interview, October 20, 2015)

The digital literacy factors and indicators explained above were employed in the questionnaire that contained 54 questions. The collection of data was analyzed by the correlation of variables as shown in Table 1. The parameters of the digital literacy scale for Thai undergraduate students were organized into two levels. The first order factor analysis was for the indicators; and the second order factor analysis was for factors (Table 2).

In Table 1, the correlation matrix analysis of the 12 observed variables shows the correlation among latent variables with a significant level of statistic correlation at 0.01. The correlation value ranged between 0.031 and 0.612. The results of the CFA were then used to test the construct validity of the research latent variables (Table 2) and harmony correlation was found of the empirical data contained in this research model (chi-square = 25.007 for 21

degrees of freedom; p = .247; RMSEA = 0.0127; RMR = 0.00658; GFI = 0.996; AGFI = 0.987; Model AIC = 139.007; Saturated AIC = 156.000; Model CAIC = 485.328; Saturated CAIC = 629.913).

The first order factor analysis of the 12 indicators revealed complete standardization weights from 0.572 to 0.905, and reliability ranging from 0.327 to 0.820. The weight factors of latent variables (operation skills, thinking skills, collaboration skills, and awareness skills) were 0.802, 0.897, 0.894 and 0.536, respectively. The value of reliability according to Cronbach's alpha coefficient of correlation was 0.644, 0.804, 0.799, and 0.288, respectively. The measurement model of digital literacy for undergraduates is shown in Figure 2.

Conclusions and Discussion

Digital literacy consists of a dynamic combination of mind set, behaviors, and skills that are employed to change and enhance undergraduate students through the use of digital information, technology, and media. The research addressed the definition, application, and factors of digital literacy which are appropriate to Thai undergraduate students through document research and interview. The definition of digital literacy is the set of abilities to utilize and be aware of digital information, technology, and media for searching, evaluating, creating, and communicating as needed. The definition combines ICT literacy and information literacy.

Table 1
Correlation coefficients of characteristic variables on digital literacy scale for Thai undergraduate students

Var	Cog	Inv	Pre	Ana	Eva	Cre	Tea	Net	Sha	Eth	Leg	Saf
Cog	1.000											
Inv	0.514	1.000										
Pre	0.499	0.612	1.000									
Ana	0.482	0.404	0.561	1.000								
Eva	0.377	0.321	0.359	0.536	1.000							
Cre	0.361	0.364	0.422	0.496	0.520	1.000						
Tea	0.430	0.358	0.511	0.488	0.425	0.496	1.000					
Net	0.395	0.320	0.438	0.422	0.376	0.441	0.567	1.000				
Sha	0.448	0.469	0.508	0.483	0.415	0.440	0.513	0.549	1.000			
Eth	0.271	0.086	0.218	0.345	0.429	0.345	0.351	0.326	0.225	1.000		
Leg	0.168	0.031	0.162	0.260	0.357	0.263	0.267	0.256	0.167	0.702	1.000	
Saf	0.299	0.107	0.211	0.329	0.369	0.325	0.352	0.331	0.279	0.575	0.578	1.000
Mean	3.675	2.794	3.412	3.658	3.756	3.778	3.842	3.874	3.527	4.052	4.040	4.102
SD	0.674	0.907	0.755	0.681	0.721	0.670	0.653	0.724	0.802	0.636	0.683	0.710

Table 2
Estimated parameters and statistics of digital literacy scale for Thai undergraduate students

| Variable	SS	SE	T	SC	FS	R^2
First order factor analysis						
Operation skills (OPE)						
Cog	0.523	–	–	0.776	0.682	0.602
Inv	0.585	0.037	15.959	0.649	0.314	0.421
Pre	0.431	0.042	10.300	0.572	0.048	0.327
Thinking skills (THI)						
Ana	0.536	–	–	0.787	0.672	0.619
Eva	0.489	0.026	18.894	0.678	0.191	0.460
Cre	0.513	0.026	19.903	0.766	0.541	0.586
Collaboration skills (COL)						
Tea	0.516	–	–	0.790	0.653	0.624
Net	0.519	0.025	21.135	0.717	0.306	0.514
Sha	0.602	0.029	20.783	0.751	0.423	0.564
Awareness skills (AWA)						
Eth	0.574	–	–	0.905	1.173	0.820
Leg	0.454	0.029	15.644	0.666	0.141	0.444
Saf	0.616	0.039	15.787	0.866	0.799	0.750
Second order factor analysis						
OPE	0.802	0.039	20.348	0.802	–	0.644
THI	0.897	0.039	23.048	0.897	–	0.804
COL	0.894	0.037	23.893	0.894	–	0.799
AWA	0.536	0.033	16.059	0.536	–	0.288

$\chi^2 = 25.007$; df = 21; $p = .247$; RMSEA = 0.0127; RMR = 0.00658; GFI = 0.996; AGFI = 0.987
Model AIC = 139.007, Saturated AIC = 156.000, Model CAIC = 485.328, Saturated CAIC = 629.913

ICT skills enable active participation in a society where services and cultural offerings are computer-supported and distributed on the Internet. Gilster (1997, p. 15) defined DL to be "a special kind of mind-set about mastering ideas — not keystrokes." Likewise, information literacy focuses on one of the key aspects of a knowledge society such as the ability to locate, identify, retrieve, process, and use digital information optimally as well as the definitions of UNESCO (Cornell University, 2009; Karpati, 2011) and the American Library Association (2013).

The qualitative data were analyzed to determine the factors and indicators of digital literacy for undergraduate students. The researchers used confirmatory factor analysis (CFA) to verify the factors and indicators. CFA is a powerful tool for the study of complex areas of behavioral scientific concern (Kerlinger & Lee, 2000). It is also the exploratory factor analysis technique most used in factor analysis to uncover latent variables or factors (Jöreskog & Sörbom, 1989). The construct validity of research latent variables was found through the harmony correlation of empirical data contained in the digital literacy model.

Operation, thinking, collaboration, and awareness skills are mandatory factors in digitally literate students. Operation skills refer to technical competency in the effective use of technology. In order to possess operation skills, students must also demonstrate thinking skills which include a high order of analytical thinking. Thinking skills allow students to have understanding and positive attitude towards technology. They must also think creatively to produce work that is useful for themselves and the masses. Moreover, digital technology facilitates collaboration and interaction and therefore, students must also possess collaboration skills and awareness skills. They must be aware of the impact of digital use regarding security for themselves and the society. Digital literacy includes thinking, evaluating, and demonstrating ethics and netiquette.
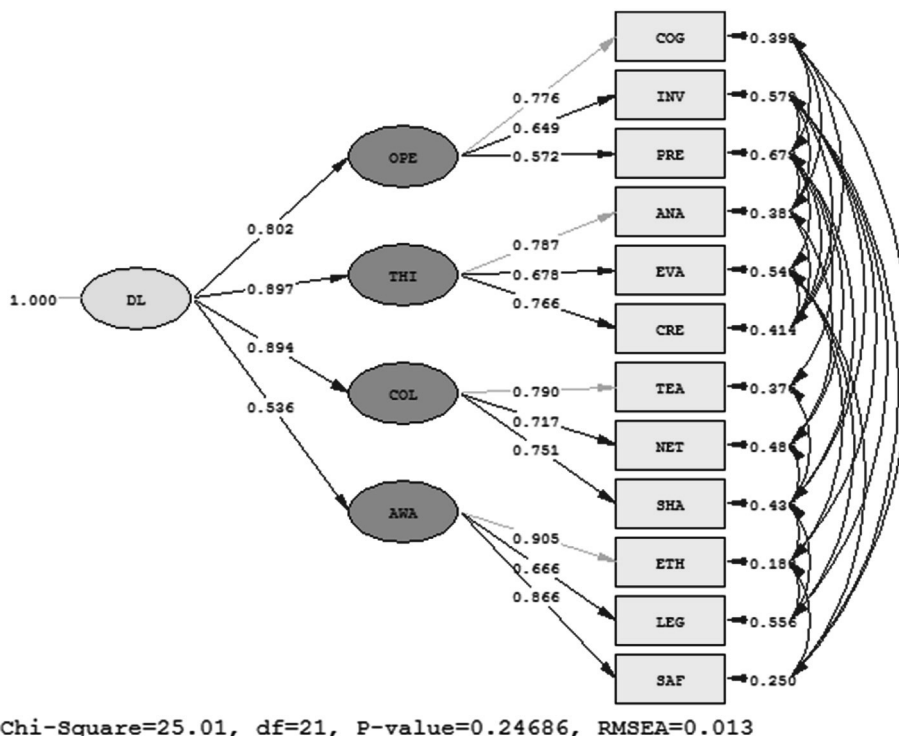
Figure 2 Measurement model of digital literacy for undergraduates

Our findings on digital literacy factors support the following previous studies: Van Deursen and Van Dijk (2009), who examined 4 skills of digital literacy: operational skills, formal skills, information skills and strategic skills; Li and Ranieri (2010) and Cartelli (2010), who studied three dimensions of digital literacy: technology, cognitive domain, and ethics or social relationship; Ng (2012), who studied technical, cognitive, and social-emotional factors of digital literacy; Hall, Nix, and Baker (2013), Murray and Pérez (2014), and Shopova (2014), who studied ICT and information literacy; and Ozdamar-Keskin, Ozata, and Banar (2015), who studied the ability to use digital learning tools, managing digital learning platforms, ability to use advanced level digital tools, and security and ethics. However, our findings did not support those of Jongsermtrakoon and Nasongkhla (2015) and Phuapan et al. (2016) who determined the following elements of digital literacy: define, access, evaluate, manage, integrate, create, and communicate.

Many digital literacy models are concerned with technical and cognitive skills in using ICT and digital information. Digital literacy requires more than just the ability to use software and digital devices, but must also include social ethics. Leahy and Dolan (2010) noted that digital literacy has changed continually with rapid advances in technology. Therefore, application of digital literacy in academic life can enhances the students' sustainable lifelong learning in light of rapid changes in technology.

Recommendations

Higher education has encountered digital technology and media beyond institutional constraints. To practice and promote students to be digitally literate is an essential responsibility of universities. The research results, especially the factors and indicators, have been adapted into a digital literacy test for assessing students. The evaluation of digital literacy among students at each individual or type of university would perceive their strength and weakness in order to plan DL promotion. Moreover, the universities must apply digital literacy to teaching pedagogy and to developing appropriate skills for students in the 21st century.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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