THE PROTOTYPE OF BLENDED LEARNING'S SUPPORT SYSTEM TO IMPROVE THE PRE-SERVICE TEACHER'S DIGITAL LITERACY

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ABSTRACT

Various blended learning models have been developed, but none of them have focused on support systems to improve the digital literacy of preservice teachers. This study aims to produce a prototype of a blended learning support system that can improve the digital literacy of preservice teachers. This type of research is research and development using a 4D model. This research was conducted at Universitas Negeri Padang and started with a needs analysis of 168 students to develop a blended learning prototype. The prototype was tested on six experts, six lecturers, and six students in the limited test and 50 students at the dissemination stage. The data collection instrument used observation and questionnaires. The data were analyzed using descriptive statistical analysis. The results show that the validity of the blended learning support system to improve the digital literacy of preservice teachers was in the very valid category. All indicators from the experts were higher than indicators from the lecturers. Although each support system was assessed differently by the experts and the lecturers, overall the digital literacy components in each support system were declared valid. The results of this study contribute to the development of digital literacy for preservice teachers by integrating digital literacy skills into a blended learning support system that includes lesson plans, content, and activities on the LMS as well as digital literacy-based assessments.

Keywords: blended learning, support system, digital literacy

INTRODUCTION

The COVID-19 pandemic has sped up the application of online learning throughout the world in educational institutions (Aguilera-Hermida, 2020; Dhawan, 2020; Mishra et al., 2020). When fully online learning is carried out, students study at home. During the COVID-19 pandemic, students took advantage of online learning. After the Covid-19 pandemic, or in the new normal era, learning will be carried out by combining face-to-face with online learning, which is known as blended learning. Online and blended learning models are growing in popularity in higher education institutions because they seek to support and facilitate its implementation. The application of blended learning in universities allows students to have many experiences related to digital learning because students can take advantage of tools, software, and information when studying in a blended learning environment (Mery & Newby, 2014). This provides an advantage for students to study independently and collaboratively by utilizing technology for learning. On the other hand, if technology cannot be used wisely in learning, then this technology and information will be irrelevant to the student. Thus, digital literacy competence is

necessary for students to learn.

The basic competencies of digital literacy are present in every student but need to be improved upon. Digital literacy is important because there is a positive relationship between digital literacy and student achievement (Fairlie et al., 2010; Harris & Brown, 2009; Lopez Islas, 2013). This ability is increasingly needed, especially in the implementation of blended learning, because students must be technologically literate to succeed at blended learning (Tang & Chaw, 2016). Moreover, digital literacy is also a fundamental component in blended learning settings where the success of the blended learning environment is determined by the digital literacy practices of the learners (Tang & Chaw, 2016).

Digital literacy is important for student-teacher candidates so they meet their expectations regarding their smart use of technology because students work in a technology-based educational environment. Therefore, a high-level pedagogical approach is needed to be able to prepare prospective teachers by building a blended learning support system to prepare preservice teachers with digital literacy skills. Research results on teaching faculty emphasize the need for digital literacy skills to be incorporated into the curriculum and courses (Abbas et al., 2019; Nelson et al., 2011). This effort is carried out in teacher candidate universities because university professors play an important role in the development of the digital literacy of students who are prospective teachers (Akayoglu et al., 2020). To meet future industry demands, universities will need to incorporate these skills in undergraduate and graduate programs (Becker et al., 2017) and embed digital literacy in their curricula (Abbas et al., 2019).

The awareness of digital literacy in preservice teachers is still relatively low. Students only have the main/basic skills of digital literacy related to the use of information and communications technology (ICT) (Ozdamar-Keskin et al., 2015). The results of this study indicate that preservice teachers have low digital literacy skills. Furthermore, the results of observations made by researchers at Universitas Negeri Padang, Indonesia, show that 70% of students do not understand how to choose and use information technology in a blended learning environment. Students also stated that they were not familiar with the supporting tools in the learning management system (LMS) and had difficulty understanding the material presented in it.

Students in higher education need to have digital literacy competencies, including at universities that educate the preservice teacher, so they can thrive in the future and prepare their students to be digitally literate. Currently, preservice teacher digital literacy competencies are at a basic level. This level can be increased to intermediate and advanced so that preservice teachers understand the use of digital tools and information to find, assess, create, and communicate the information they get (Abbas et al., 2019; Akayoglu et al., 2020). The spread of digital literacy skills can be done early by preparing preservice teachers while they are in college. One of the literacy skills they need is the ability to utilize information technology to support online or blended learning.

This online and blended application has limitations in preparing students to acquire digital literacy. Several relevant studies have been conducted by previous researchers that develop blended learning content to improve 21st-century skills-based on the 4Cs (Ilyashenko et al., 2019; Mahande et al., 2021) and increases student engagement (Dwivedi et al., 2019; Fisher et al., 2018; Green et al., 2018; Serrano et al., 2019). Other studies also developed etutorials to improve digital literacy in universities (McGuinness & Fulton, 2019), digital literacy-based modules (Ikpeze, 2018), and assessment instruments (Covello, 2010). The research conducted so far has not specifically used a support system that integrates digital literacy in blended learning. This is needed because in designing blended learning it is necessary to integrate interconnected support systems (Calderón et al., 2021). This study uses a support system as a design for learning that includes content and activities in the LMS and digital literacy-based assessments. This support system is a component of the learning model that is implemented to achieve the model's goals (B Joyce et al., 2015). The support system developed uses the main LMS platform, because it has been specifically designed for learning activities and it supports the integration of digital literacy in blended learning.

Our study aims to develop a prototype of a blended learning support system to increase the digital literacy of prospective teachers. This research contributes to providing a prototype of

a complete and comprehensive support system to prepare preservice teachers to acquire digital literacy skills that are relevant to the needs of future teacher candidates.

LITERATURE REVIEW

Blended Learning Preservice Teachers in Universities

Although there are data on teacher readiness to use ICT, teachers in the field still need ICT integration training in the classroom (Qasem & Nathappa, 2016). In integrating ICT into this class, digital literacy skills are needed so that the technology is applied correctly. For universities that become Education Personnel Education Institutions (LPTK) teaching preservice teachers, they can apply blended learning in an effort to improve the digital literacy skills of preservice teachers. If preparing preservice teachers with only one of the learning approaches, either face-to-face or fully online, then only part of the competencies would be obtained by preservice teachers. For example, preservice teachers who study with a stand-alone course increase technology knowledge and technology pedagogical knowledge, while those who learn through technology-infused courses can increase content knowledge and pedagogical knowledge (Buss et al., 2015). The recommendation is to apply blended learning because this learning system combines the best of face-to-face and the best of online learning (Bersin, 2004; Rahmi et al., 2021). The learning that preservice teachers have received has had a significant impact on their ability to integrate ICT into learning (Aslan & Zhu, 2017).

The implementation of blended learning cannot be separated from the learning model support system. This support system is one of the components of other learning models that include syntax, reaction system, social system, and accompaniment impact (Joyce et al., 2008, 2015). The blended learning support system was developed based on the needs of the learning model. The support system for implementing the model can be in the form of a blended learning lesson plan, content in the LMS, blended learning activities, and an assessment system that can be used as an instruction guide in the application of the learning model (Kirschner et al., 2006). Guidance is needed to support the application of the model, like using a support system for inquiry-based instruction,

(Vorholzer & von Aufschnaiter, 2019). Learning models that develop digital literacy need to be built from a support system based on digital literacy in the form of tools and teaching content that encourages digital literacy skills for preservice teachers in a blended learning environment.

Digital Literacy

The urgency of digital literacy for preservice teachers is that it is a skill that is needed throughout life (Alexander et al., 2017). As long as digital information and technology develop, digital literacy skills will be in demand. These skills are the interest, attitude, and ability of individuals to use digital technology and communication tools appropriately to access, manage, integrate, analyze, and evaluate information, to construct new knowledge, and to create and communicate with others using intellectual and technical talents. Digital literacy skills lead someone to search, manage, evaluate, and integrate digital information well (Greene et al., 2014).

Digital literacy skills empower students to perform basic tasks such as understanding hardware, software, and the basic online operations needed to adapt to society (Abbas et al., 2019). These basic online operational skills include the ability to manage email, conduct searches, and fill out online forms. Hardware-related skills, such as how to use the keyboard and operate touch technology, also include the ability to process cities, how to process files on a laptop, and how to manage privacy settings on a cellphone.

These skills improve the quality of people's lives, provide opportunities to interact with others, and allow access to government services. Digital literacy skills make it possible for everyone to use technology in an appropriate and useful way and include the ability to evaluate technology critically when finding and providing information. Therefore, in the future more digital literacy skills will be needed, including in the teaching profession. Preservice teachers need to be prepared with digital literacy skills through a system that has been designed with blended learning. The subdisciplines of digital literacy skills include information literacy, computer literacy, media literacy, communication literacy, visual literacy, and technology literacy (Covello, 2010).

Information literacy is the skill of finding sources, analyzing and synthesizing materials,

evaluating the credibility of sources, ethically and legally using and citing sources, and focusing on topics and formulating research questions accurately, effectively, and efficiently (Walsh, 2015). This includes knowing when and why we need information, where to find it, and how to evaluate, use, and communicate it ethically.

Computer literacy is the ability to understand how to use computers and application software for practical purposes (Martin & Grudziecki, 2006). Today's students need a higher level of computer literacy to succeed in school and the future, which means preservice teachers need to be prepared with adequate digital literacy skills to teach students (Makhmudov et al., 2020). This ability contributes to computer optimization in learning so that learning becomes more interesting and challenging (Tumburku et al., 2019).

Media literacy is a communication competency that includes the ability to access, analyze, evaluate, and communicate information in various forms, including print and digital (Martin & Grudziecki, 2006). This is media that is appropriate to the context and consists of classic and new media, analog and digital media, and personal, mass, and social media (Simons et al., 2017).

Communication literacy is the ability to communicate effectively both individually and collaboratively. Digital literacy is often associated with the ability to read and is related to visual media and visual literacy. Terms such as media literacy, computer literacy, or reading literacy are sometimes used for communication literacy. Without the ability to read, one cannot communicate with others through text, and without visual literacy, messages cannot be understood. Communication literacy is more general than just this special ability (Ghasemi & Rasekh, 2020).

Visual literacy is the ability to read, interpret, and understand the information presented in pictorial or graphic images. This includes the ability to convert any type of information into images, graphics, or forms that help communicate information. Visual literacy is a group of competencies that enable humans to distinguish and interpret visible, natural, or constructed actions, objects, and/or symbols that they encounter in the environment (Hattwig et al., 2013; Stokes, 2002)

Technological literacy is the ability to use computers and other technologies to improve learning, productivity, and performance (U.S. Department of Education, 1996). This literacy is recognized as important by preservice teachers because it supports creating new things in light of technological developments (Yigit & Ozturk, 2012). Other teachers have proven that technological literacy shows pedagogical elements in learning to be more authentic (Cydis, 2015).

Digital literacy is difficult to achieve using only a face-to-face or fully online mode. Digital literacy competence develops optimally if it is carried out in a blended learning environment. In addition to the importance of digital literacy for student survival in the future, it can also increase the effectiveness of learning in blended learning environment (Tang & Chaw, 2016). Digital literacy in blended learning can be created if it is supported by a system that focuses on digital literacy. Therefore, we developed a blended learning support system to improve digital literacy that starts with a semester learning design and maps materials, content, and activities on the LMS based on a digital literacy criteria that we have defined in this study.

METHODOLOGY

Development Procedure

The research aims to develop and validate a blended learning support system to improve the digital literacy skills of preservice teachers. This research and development follows a 4D model procedure that comprises of four steps: define, design, develop, and disseminate (Thiagarajan et al., 1974). This model was chosen because the procedure is systematic and begins with a needs analysis at the defined stage. This model is also relevant for developing learning products that focus on student-centered learning (Reigeluth & An, 2020).

Location and Research Subjects

This research was conducted at a preservice teacher university at Universitas Negeri Padang, Indonesia. The initial data for development was taken from various other preservice teacher universities in Indonesia so that the support system we developed, based on the needs of the university, can be disseminated. The subjects of this study consisted of six experts, six lecturers, and six students, followed by 50 students at the dissemination stage. The data came from a survey conducted on 168 students about the needs of a teacher-producing institution. Furthermore, the experts and lecturers

tested the validation of the support system we developed. The experts involved in this research were instructional designers and elearning, multimedia learning, and content experts.

Data Collection Techniques and Instruments

The data collection instrument we used was observation and questionnaires. Observations were made to collect data on a needs analysis and the readiness of campuses, lecturers, and students to implement blended learning. In addition, the needs analysis data were also collected by distributing need analysis instruments. This instrument consisted of device readiness, learning readiness in blended learning, and the need for digital literacy skills. The instrument used was a 5-point Likert scale ranging from *strongly disagree* (1), *disagree* (2), *neutral* (3), *agree* (4), to *strongly agree* (5). The content validity test of the instrument was carried out by experts in various disciplines including learning media, learning evaluations, learning models, and strategies.

Data Analysis

The data obtained from all stages were analyzed using descriptive data analysis techniques.

Figure 1. Prototype of Support System to Improve Digital Literacy

Course Identity				
Course Description				
Learning Outcome				
Program Map/sequence of material and activity time				
Weekly Activities (1–16)				
Weekly				
Component	**Format**	**Activities**		**Skills**
Topic description	Text, audio, video	Delivering weekly topics and their relation to digital literacy	Introduction activity	Information literacy
Purpose	Text, audio, video	The purpose of studying the topic and improving digital literacy		Information literacy
Material	Text, visual, audio-video in the form of file book, handout, page, URL	Delivering material both face-to-face and online using Moodle	Core activity	Information, Computer, Media, Communication, Visual, and Technology literacy
Discussion	Use features like forum, chat, and video conference such as, BigBlueButton and Zoom	Face-to-face discussions and working in small groups. Online discussion conducted using the LMS		
Individual and/ or collaborative tasks/activities	Assignment feature	Each week varies between individual assignments, collaborative tasks, and reflection	Closing activity	Communication, Information, Computer, and Technology literacy
Quiz	Quiz feature	Assessing the achievement of goals and increase digital literacy skills		Information, Computer, and Technology literacy
References of weekly	Text and link			All skills
Next weekly/ topic				
How to learn	To achieve learning outcomes and improve digital literacy skills			
How to grade				
References	Print and digital			

The data analysis is presented in the form of tables and pictures from experts, lecturers, students, and other relevant sources related to the development of a blended learning support system.

RESULTS

Define Stage

The define stage started by observing the campus facilities that support the implementation of blended learning. The campus had an LMS, internet capacity, trained lecturers, and a professional technical team. Then we distributed a questionnaire (Cronbach's Alpha 0.884 means the instrument has passed the minimum value and is reliable to use) to preservice teacher students regarding their learning needs in a blended learning environment (98% of students) and the readiness of the equipment to support lectures with a blended learning system (95%). Regarding digital literacy skills, the average student had a score of 2.1 from a range of 1–5. This needs analysis was carried out because not all students were categorized as digital natives and not all students have the same digital literacy skills (Alexander et al., 2017). Based on the results of the needs analysis, the support system design process was then carried out.

Design Stage

This stage began with conducting a literature review related to theories relevant to the support system, blended learning, and digital literacy for preservice teachers. After that, we identified a support system for blended learning that needed to be designed and developed in to instill in preservice teachers digital literacy. We also identified the features on the LMS that can facilitate learning activities in an effort to improve the digital literacy skills of preservice teacher students. Based on this, we designed a prototype support system to apply blended learning to improve the digital literacy of preservice teachers. This stage takes an initial prototype of a blended learning support system to improve the digital literacy of preservice teachers (Figure 1).

This support system was a component of one model in addition to syntax, reaction principles, and social systems (Joyce et al., 2015). The model required a support system, in this case, tools and teaching content that supports digital literacy skills for prospective teachers. At this stage, the initial concept of the support system was designed according to the needs analysis. The result was a model support system comprised of lesson plans and the material presented on the LMS in text, image, audio, and video formats, as well as learning achievement assessment instruments and digital literacy skills improvement achievements. All components of the support system were designed and developed based on subdisciplines and the stages of digital literacy skills. Digital literacy material was integrated into 14 interactive teaching materials that were embedded in the institution's LMS. All the materials were designed according to learning scenarios to improve digital literacy skills. The material variations consisted of text, images, audio, and video as well as animations.

Develop Stage

At the development stage, the support system (learning planning, the material presented on the LMS in text, image, audio, and video formats, as well as an instrument for assessing learning achievement and digital literacy skills improvement achievements) was made into a prototype. All the products were presented in the form of semester learning plans, LMS content, LMS activities, and validated assessments. This prototype was validated by experts and lecturers as users.

Based on the results of the expert appraisal, the validation coefficient of Aiken's 0.60 meant that the instrument was valid. Meanwhile, in the instrument reliability test, the results of Cronbach's Alpha 0.971 meant that the instrument has passed the minimum value and was reliable to use (Eisingerich & Rubera, 2010). The instrument was validated by experts who assessed the blended learning support system. Based on their input and assessment, we revised the instrument and improved the product. The experts and lecturers conducted further assessments after accessing the blended learning support system.

In general, the responses of experts and lecturers were very high because the blended learning support system provided written and virtual feedback and communication facilities for listening and exchanging thoughts, knowledge, and learning activities to improve the digital literacy skills of prospective teachers. The following are the results of the validation carried out by experts and lecturers on the lesson plans, LMS content, activities in the LMS, and assessments.

The experts conducted validity tests and the

Table 1. Analysis of the Digital Literacy-based Blended Learning Semester Learning Design Support System

No	RPS items rated	Experts (*n*=6)	Lecturers (*n*=6)
1	RPS includes activities to find, analyze, synthesize, and evaluate information in blended learning	4.16	3.83
2	RPS lists activities using computers and software that are relevant to the needs of teachers	4.16	3.83
3	RPS comprises activities to find, use, and evaluate print and digital media in blended learning	3.83	3.66
4	RPS contains activities to communicate effectively both individually and collaboratively in blended learning	3.83	3.50
5	RPS includes reading, understanding, distinguishing, and communicating information in the form of images, graphics, symbols, and other objects in blended learning	3.83	3.50
6	RPS involves activities using computers and other technologies to solve problems/tasks and productively learn in blended learning	3.66	3.16
Average		3.91	3.58

lecturers and students conducted practicality tests. Table 1 shows the results of the validity test carried out by the experts on the lesson plan, which are in the very valid category. Although the value of the criteria given by experts was different, in general, the expert's responses stated that the support system is valid. Meanwhile, the results of practicality trials for lecturers as users were also declared practical. In conclusion, expert and lecturer responses were very valid because the blended learning lesson plan was designed to improve students' digital literacy.

Based on Table 1, the digital literacy-based blended learning lesson plan for student-teacher candidates was declared valid by the experts and practical by the lecturers.

Table 2 shows the results of the validity test of digital literacy-based blended learning content by experts, which are in the very valid category. The results of practicality tests conducted by lecturers and students are also included in the very practical or good category. In general, the responses of experts, lecturers, and students were very good for digital literacy-based blended learning content. Experts rate it well for all items. Meanwhile, the lecturers assessed the availability of a variety of content (item 3), communicative content (item 4), and content visualization to clarify material on certain topics (item 5) as high. The content was also well received by students with the availability of a content variety and communicative content (items 3 and 4).

Hence, from these results, digital literacy-based blended learning content for preservice teacher students was declared valid by experts and practical by lecturers and students.

Table 2. Analysis of Support Systems for Digital Literacy-based Blended Learning Content

No	Content items (text, images, audio, video, links) on the LMS being rated	Experts (*n*=6)	Lecturers (*n*=6)	Students (*n*=6)
1	Blended learning content facilitates students to find, analyze, synthesize, and evaluate information	4.50	3.71	3.83
2	Content in various formats is accessed using computers and software that applies to the needs of teachers	4.50	3.85	4.33
3	Print and digital blended learning content facilitates finding, using, and evaluating a variety of media	4.16	4.00	4.17
4	Blended learning content encourages students to communicate with lecturers and other students	4.50	4.00	4.80
5	Visual content can be read, interpreted, understood, distinguished, and communicated	4.33	4.14	4.80
6	Blended learning content helps students improve learning, productivity, and performance	4.33	3.71	4.17
Average		4.38	3.90	4.36

Table 3. Analysis of Support Systems for Digital Literacy-based Blended Learning Activities

No	Graded blended learning activity items	Experts (*n*=6)	Lecturers (*n*=6)	Students (*n*=6)
1	Activities encourage students to find, analyze, synthesize, evaluate, and convey information	3.83	3.42	4.00
2	Activities urge students to use computers and software that are relevant to the needs of teachers	3.66	3.28	4.00
3	Activities direct students to use print and digital media to find, use, and evaluate these media	3.66	3.28	4.33
4	Synchronous (video conference, chat) and asynchronous (discussion forum) activities for communication/interaction	4.00	3.28	4.00
5	Blended learning activities lead students to "read," interpret, and understand visual information	4.00	3.71	4.17
6	Blended learning activities allow students to use computers and other technologies	3.50	3.42	4.50
	Average	3.77	3.40	4.17

Table 3 shows the results of the validity test for activities carried out by experts, which are in the very valid category. The results of the practicality tests conducted by lecturers and students are also in the very practical category. The results of the validity and practicality tests for this activity were considered good, especially for items 4 and 5 by experts, item 5 by lecturers, and, according to students, all the activities encouraged them to become digitally literate.

This means that digital literacy-based blended learning activities for prospective teacher students have been declared valid by experts and practical by lecturers and students.

Table 4 shows the results of the validity and practicality tests for the digital literacy-based blended learning assessment. Experts, lecturers, and students rated it a very valid category. The blended learning assessment was developed on a case-by-case basis and was integrated into something that encourages student digital literacy. An example of a successful strategy was presenting a case that assists students to search for information from various printed and digital sources, analyze information, select the relevant information, and communicate it. In the series of assessments, the correctness of the information found by students, the method used, the media and learning resources, and choosing what method and how to communicate it were assessed. Assessments that can be done to improve digital literacy are case based and project based.

The digital literacy-based blended learning assessment for preservice teachers was declared valid by experts and practical by lecturers and students.

In conclusion, the experts have stated that the lesson plans, content, activities in LMS, and blended learning assessments are valid to improve students' digital literacy. Meanwhile, the lecturers

Table 4. Analysis of Digital Literacy-based Blended Learning Assessment Support Systems

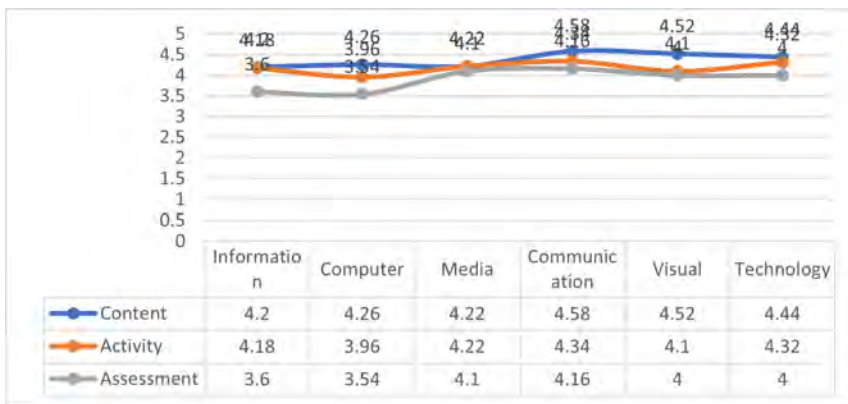| No	Rated assessment items	Experts (*n*=6)	Lecturers (*n*=6)	Students (*n*=6)
1	Items assess students' information literacy skills	4.00	3.83	3.97
2	Items evaluate students' computer literacy skills	4.33	3.50	3.83
3	Items consider students' media literacy skills	3.83	3.50	4.00
4	Items value students' communication literacy skills	4.00	3.83	4.00
5	Items assess students' visual literacy skills	4.00	4.00	4.00
6	Items rate students' technological literacy skills	4.50	3.83	3.83
	Average	4.11	3.73	3.97

and students, as users, stated that these are practical elements for the support system.

Disseminate Stage

The next stage was testing the prototype for a wide range of users. We distributed the prototype to 50 students from two elearning development classes. The test results show that the prototype of a blended learning support system to improve digital literacy was practical. The test results were in the very practical category: Content 4.37, Activities 4.19, and Assessment 3.9. The distribution of test data on content, activity, and assessment blended learning to improve digital literacy can be seen in Figure 2.

Figure 2. The Results of the Trial Deployment of the Blended Learning Support System

	Information	Computer	Media	Communication	Visual	Technology
Content	4.2	4.26	4.22	4.58	4.52	4.44
Activity	4.18	3.96	4.22	4.34	4.1	4.32
Assessment	3.6	3.54	4.1	4.16	4	4

In Figure 2 it can be seen that Content has a higher practical value than the other components of the blended support system. For Media literacy skills, Content, Activity, and Assessment have almost the same value (4.22, 4.22, and 4.21). The three components show a difference for Computer literacy with a difference in the value of 0.7 between Content and Assessment. All these components of the six aspects of digital literacy were declared very practical with values above 3.5. Hence, this support system was declared valid by experts and practical by users.

DISCUSSION

Blended learning to improve digital literacy for students at Education Personnel Education Institutions is assisted by a support system that integrates digital literacy elements from learning planning, LMS content, and activities on the LMS, to digital literacy-based assessments. The elements of this support system synergize with each other for implementing learning, including blended learning. Learning planning is only a document, and without content support and an LMS delivery system, learning outcomes from lectures are difficult to achieve. Likewise, without activity scenarios on the LMS and face-to-face meetings, content is only a display of material. To improve students' digital literacy through blended learning, the syllabus, content, activities, and assessments should be designed and developed based on digital literacy. For example, the syllabus should include activities that encourage students to find, analyze, and evaluate information. Lecturers and instructional designers need to prepare learning activities on the LMS and face-to-face activities that do not overlap because lectures are in a blended learning model. Digital literacy-based learning activities are supported by content provided by the lecturer team that serves as the main source for students. When students have valid recommendations from their lecturers, students feel they have a minimum standard that they must meet. These activities need to be assessed using a digital literacy-based assessment method to judge if the objectives and processes carried out have achieved their goals.

In the LMS, the presentation of this support system begins by displaying the learning outcomes and the syllabus. Progress each week follows the structure of the study material/topic, objectives per topic, and the constructivist learning activity scenarios based on the selected blended learning model. The content presentation should support activities in text, image, audio, video, and multimedia formats. And finally closed with authentic assessment activities related to student learning activities. In addition, digital literacy skills need to be assessed at the beginning and the end of the semester to see the progress of the students in their digital literacy skills. The presentation and delivery of content must be adapted to the selected blended learning model (Staker & Horn, 2012). Determining the best model is important because that makes it easier for lecturers to identify the learning resources and activities, as well as strategies and methods, that are appropriate for

face-to-face and/or online learning.

Before discussing the results in detail, it should be emphasized that the purpose of this research is to produce a valid blended learning support system to improve the digital literacy of Education Personnel Education Institution (LPTK) students. This blended learning system offers planning, content, and learning resources, as well as blended learning activities that can create learning experiences related to the digital literacy skills information, computer, media, communication, visual, and technology literacy. To produce this learning experience, the digital literacy skills need to be properly identified, developed, and integrated into blended learning support systems.

Information Literacy

Information literacy is taught through the delivery of topics and learning objectives as well as how students are active in finding the information relevant to the topic to achieve a learning objective (item 1 in each table above). Information literacy is the skill of finding sources, analyzing and synthesizing materials, evaluating the credibility of sources, ethically and legally using and citing sources, focusing on topics, and planning questions accurately, effectively, and efficiently (Meyer et al., 2008). Students are taught how to evaluate the information they receive online, including information obtained through social media (Akayoglu et al., 2020). In this study, instructions (Table 1, item 1) and content (Table 2, item 1) were designed to facilitate students in developing information literacy skills. This literacy is important for, and a prerequisite for participating effectively in, the information society because of the students' daily need for information and their ability to identify, find, evaluate, organize, and effectively create, use, and communicate information to solve problems in the information society (Martin & Grudziecki, 2006). Research conducted in Australia found that the information literacy of new students was low and worsened when the skills were not developed during the study program (Barr et al., 2020). Therefore, in the framework of this blended learning support system, plans, activities, and assessments are integrated with these information literacy skills. If these skills continue to be developed by students in their study program, they will grow from usage competency to the stage of innovative and creative transformation.

Computer Literacy

Computer Literacy is related to students' understanding of how to use computers and application software for practical purposes (Covello, 2010) from the mastery phase, the application phase, and to the reflective phase (Martin & Grudziecki, 2006). These phases can be achieved through learning activities in a blended learning environment because the transformation of learning to blended learning is one way to improve digital literacy (item 2 in each table), including computer literacy (Napier et al., 2011). Computer literacy skills can be improved by integrating computer literacy-based activities into learning (Nelson et al., 2011). Therefore, the scenario of blended learning activities is designed (Table 1, item 2) in this study to be able to increase phase by phase in each learning activity. Learning activities are ordered from activities related to the simplest computer literacy skills to more complex levels of technology use and integration. The frequency of using computers directly in blended learning can increase students' ability and sensitivity to using digital technology, especially computers and other communication tools appropriately (Table 3, item 2). This accuracy refers to the ability to access, manage, integrate, and use computers to communicate effectively with others (Van Joolingen, 2004).

Media Literacy

One of the blended learning support systems is content in a delivery system that is tailored to the selected blended learning model. The large number of media that can be accessed by students requires them to have digital literacy skills so their learning activities can be effective. This digital literacy can be enhanced through a series of communication competencies, including the ability to access, analyze, evaluate, and communicate information (item 3 in each table) from certain media in various forms, including printed and nonprinted (Covello, 2010). Media literacy is more focused on various media genres and the way messages are constructed and interpreted. The characteristics of the writer/sender and the receiver are very important in understanding the meaning of the message and its content. Information literacy tends to focus on the way information is accessed and its content evaluated (Table 2, item 3) (Martin & Grudziecki, 2006). Media literacy can be integrated into learning in several ways (Table 3, item 3) that can be

adapted to the syntax of the selected blended learning model (Friesem, 2013; Friesem et al., 2014; Neag, 2015) The syntax of the blended model can be started by encouraging students to access various media in various formats in certain subjects (Table 1, item 3). Another way is by implementing projects that focus on media literacy in several activities and various courses (Simons et al., 2017).

Communication Literacy

The blended learning support system needs to help improve communication literacy because the ideal learning activity must contain communication (Table 3, item 4), both lecturer communication with students and student communication with each other. This is evidenced by the expectations and diagnosis of student needs for discussions in blended learning (Rahmi & Azrul, 2019; Rahmi et al., 2021). This means that communication is necessary for learning. Regarding communication literacy skills, these help students communicate effectively as individuals and work collaboratively in groups by using publishing technologies such as word processing, databases, spreadsheets, drawing tools), the internet, and other electronic and telecommunication tools. Communication literacy is needed because it is the main activity of students when interacting verbally and using digital media. It is a challenge for students to be more aware and wiser in communicating using media (Martin & Grudziecki, 2006). In addition, the research shows that ownership of ICT tools does not positively correlate with communication literacy skills (Šorgo et al., 2017). Therefore, although these skills are not separate subjects, students' communication literacy skills can be improved by integrating the achievement of these skills in lectures (Tables 1, 2, 3, 4, item 4). The implication is that a set of activities is inserted into the blended learning support system to be able to train students in communication literacy skills.

Visual Literacy

The blended learning support system is developed by enriching visual content. The complexity of the visual image emphasizes the use of recommended teaching content in blended learning (Table 1, item 5). This action aims to create new knowledge for students (Table 3, item 5). Content can be presented by visualizing content based on Bloom's cognitive level to improve student understanding (Arneson & Offerdahl, 2018). Visualized content is easier for students to understand and interpret because it helps clarify certain concepts for students' cognitive abilities. Visual literacy through images becomes a powerful medium for interpreting the meanings of the content (Martin & Grudziecki, 2006). Visualization of this content is important because learning with visuals helps improve students' digital literacy skills (Hattwig et al., 2013; Stokes, 2002), namely the ability to read, interpret, and understand the information presented in pictorial or graphic images. Another skill is the ability to convert any type of information into images, graphics, or forms that help communicate information. These competencies enable humans to distinguish and interpret visible, natural, or constructed actions, objects, and/or symbols that they encounter in the environment.

Literacy Technology

Technological literacy is related to computer skills and the ability to use computers and other technologies to improve learning, productivity, and performance (Martin & Grudziecki, 2006). These skills are important in a developmental student environment with easy access to today's technology because it is potentially dangerous if they are ignored. The rapid development of technology motivates students to master all technology because they are afraid of being left behind and worry about being ostracized when they do not know the technology. This condition implicitly makes students unproductive when they have to focus on learning these skills. Therefore, when blended learning is used by students, these skills can be improved by transmitting how to select and sort out the right technology to make the students more productive (Table, item 6). It may not be explicit content in lectures, but it can be implied in learning activities compiled by lecturers and instructional designers. This idea can promote technological literacy and the application of blended learning. These pedagogical practices in blended learning can be pursued by integrating performance-based, authentic learning to encourage technological literacy in future teachers (Cydis, 2015). By practicing this for preservice teachers while they are on campus, it will have an impact on the use of technology in the teaching and learning process. This is achieved through the integration of technology tools in lesson plans, content, activities, and assessments.

All of the digital literacy components listed above can be integrated into a blended learning support system in universities. The synergy between the elements of a digital literacy-based support system (Figure 3) is needed to improve the digital literacy of preservice teachers.

Figure 3. Diagram of the Prototype of Blended Learning Support System to Improve Digital Literacy
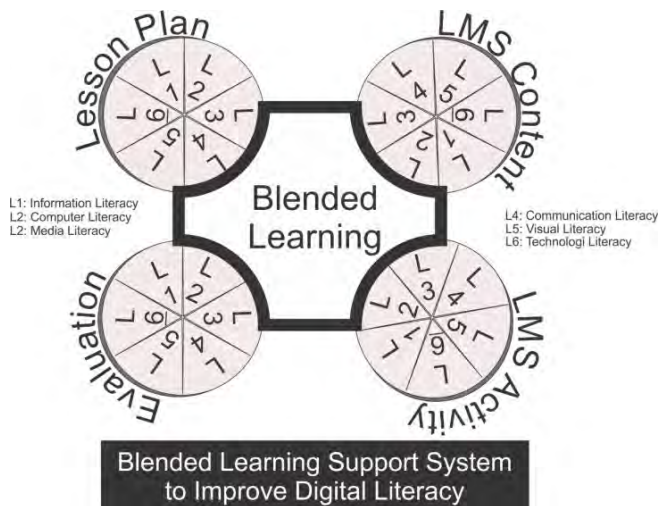

Figure 3 shows the synergy of the components of a blended learning support system that can improve students' digital literacy. The four components of the support system have met the elements and criteria for validity (Tables 1–4). The components of supporting tools, lesson plans, LMS content, LMS activity, and evaluation are developed based on digital literacy, which is expected to be used in the learning process by students. At first, it is done by imitating/receiving, then responding and managing, and finally reaching the last stage, namely characterizing (Garritz, 2013; McCoach et al., 2013). Furthermore, digital literacy can develop at three levels, namely digital competence, digital usage, and digital transformation (Martin & Grudziecki, 2006). This effort in blended learning certainly considers the harmonization of face-to-face activities with online learning so there is no overlap or repetition, including the overlap between reading skills in printed materials and digital materials (Chinta et al., 2016).

Ikpeze (2018) is a relevant study related to increasing digital literacy for teachers through providing opportunities for teachers to experiment with digital and multimodal tools, processing them

and creating opportunities for transmediation and differentiation. The same thing can also be done to preservice teachers while they are in the program. To measure the extent to which digital literacy development has been achieved, each semester students can be given a digital literacy pretest at the beginning of the lecture and a posttest at the end (Nelson et al., 2011). The support system in blended learning is considered valuable for improving the digital literacy skills of preservice teachers. This prototype can be used in other courses according to the characteristics of each class.

LIMITATIONS

This research involved three groups of subjects, namely science, social, and vocational. Although it has been declared valid and practical, this support system requires multilevel testing to get an effective support system so that it can be disseminated to other subjects besides basic physics, elearning development, and animation. In addition, this research was disseminated to ask 50 users for testing. Testing the prototype on a wider range of users may get different results.

IMPLICATIONS

This research provides both theoretical and practical implications. The theoretical implications add to the literature of lecturers and instructional designers in designing and implementing digital literacy-based blended learning for preservice teachers. The practical implication is to improve the digital literacy skills of preservice teachers, by using the blended learning support system to strengthen and enrich the components of the learning model by integrating learning plans/contents/activities/assessments based on digital literacy.

CONCLUSIONS AND RECOMMENDATIONS

The results of the research on developing a prototype blended learning support system to improve digital literacy show that all indicators of the support system are in the valid category. The support system is rated higher by experts than by lecturers, as seen in the lesson plan in which the average score is 3.91 for the expert and 3.58 for the lecturer; in the content, in which the average score was 4.38 for experts and 3.90 for lecturers in both text, image, audio, video, and multimedia formats; and in activities, in which the average score is 3.77 for experts and 3.40 for lecturers by facilitating

synchronous and asynchronous activities. Of the four support systems, content has a higher average validation value of 4.38 compared to other support systems. All the other support systems, such as lesson plans (3.91), activities (3.77), and assessments (4.11), have been declared valid. The integration of digital literacy skills in each component of the support system is very helpful in achieving the goal of increasing student digital literacy competencies. Its integration into the support system provides space for students to be compelled to learn and become proficient in and accustomed to digital literacy.

This study recommends that a valid and practical blended learning support system can be tested in a limited way in the relevant environment to obtain a set of effective support systems to improve students' digital literacy. This research can also be continued with trials on a wider sample with different material characteristics.

References

Abbas, Q., Hussain, S., & Rasool, S. (2019). Digital literacy effect on the academic performance of students at higher education level in Pakistan. Global Social Sciences Review, 4(1), 154–165. https://doi.org/10.31703/gssr.2019(IV-I).14

Aguilera-Hermida, A. P. (2020). College students' use and acceptance of emergency online learning due to COVID-19. International Journal of Educational Research Open, 1, 100011. https://doi.org/10.1016/j.ijedro.2020.100011

Akayoglu, S., Satar, H. M., Dikilitas, K., Cirit, N. C., & Korkmazgil, S. (2020). Digital literacy practices of Turkish pre-service EFL teachers. Australasian Journal of Educational Technology, 36(1), 85–97. https://doi.org/10.14742/ajet.4711

Alexander, B., Becker, S. A., Cummins, M., & Giesinger, C. H. (2017). Digital literacy in higher education, Part II: An NMC Horizon project strategic brief. The New Media Consortium.

Arneson, J. B., & Offerdahl, E. G. (2018). Visual literacy in Bloom: Using Bloom's taxonomy to support visual learning skills. CBE—Life Sciences Education, 17(1), ar7. https://doi.org/10.1187/cbe.17-08-0178

Aslan, A., & Zhu, C. (2017). Investigating variables predicting Turkish pre‐service teachers' integration of ICT into teaching practices. British Journal of Educational Technology, 48(2), 552–570. https://doi.org/10.1111/bjet.12437

Barr, N. C., Lord, B., Flanagan, B., & Carter, R. (2020). Developing a framework to improve information and digital literacy in a Bachelor of Paramedic Science Entry-to-Practice Program. College & Research Libraries, 81(6), 945–980. https://doi.org/10.5860/crl.81.6.945

Becker, S. A., Pasquini, L. A., & Zentner, A. (2017). 2017 digital literacy impact study: An NMC horizon project strategic brief. The New Media Consortium.

Bersin, J. (2004). The blended learning book. John Wiley & Sons, Inc.

Buss, R. R., Wetzel, K., Foulger, T. S., & Lindsey, L. (2015). Preparing teachers to integrate technology into K–12 instruction: Comparing a stand-alone technology course with a technology-infused approach. Journal of Digital Learning in Teacher Education, 31(4), 160–172. https://doi.org/10.1080/21532974.2015.1055012

Calderón, A., Scanlon, D., MacPhail, A., & Moody, B. (2021). An integrated blended learning approach for physical education teacher education programmes: Teacher educators' and pre-service teachers' experiences. Physical Education and Sport Pedagogy, 26(6), 562–577. https://doi.org/10.1080/17408989.2020.1823961

Chinta, R., Kebritchi, M., & Elias, J. (2016). A conceptual framework for evaluating higher education institutions. International Journal of Educational Management, 30(6), 989–1002. https://doi.org/10.1108/IJEM-09-2015-0120

Covello, S. (2010). A review of digital literacy assessment instruments (research paper). Syracuse University, School of Education/IDD & EIDE-712: Analysis for Human Performance Technology Decisions.

Cydis, S. (2015). Authentic instruction and technology literacy. Journal of Learning Design, 8(1), 68–78. https://doi.org/10.5204/jld.v8i1.222

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. Journal of Educational Technology Systems, 49(1), 5–22. https://doi.org/10.1177/0047239520934018

Dwivedi, A., Dwivedi, P., Bobek, S., & Zabukovšek, S. S. (2019). Factors affecting students' engagement with online content in blended learning. Kybernetes, 48(7), 1500–1515. https://doi.org/10.1108/K-10-2018-0559

Eisingerich, A. B., & Rubera, G. (2010). Drivers of brand commitment: A cross-national investigation. Journal of International Marketing, 18(2), 64–79. https://doi.org/10.1509/jimk.18.2.64

Fairlie, R. W., Beltran, D. O., & Das, K. K. (2010). Home computers and educational outcomes: Evidence from the NLSY97 and CPS. Economic Inquiry, 48(3), 771–792. https://doi.org/10.1111/j.1465-7295.2009.00218.x

Fisher, R., Perényi, Á., & Birdthistle, N. (2018). The positive relationship between flipped and blended learning and student engagement, performance and satisfaction. Active Learning in Higher Education, 22(2), 97–113. https://doi.org/10.1177/1469787418801702

Friesem, J. (2013). Media literacy in the K–12 classroom (2012). Journal of Media Literacy Education, 5(2), 7. https://doi.org/10.23860/jmle-5-2-7

Friesem, Y., Quaglia Beltran, D., & Crane, E. (2014). Media now: A historical review of a media literacy curriculum. Journal of Media Literacy Education, 6(2), 4. https://doi.org/10.23860/JMLE-2016-06-02-4

Garritz, A. (2013). Instrument development of the affective domain. School and corporate applications. Educación Química, 24, 538–539. https://doi.org/10.1016/S0187-893X(13)72525-4

Ghasemi, H., & Rasekh, N. (2020). Identifying dimensions of communication literacy: Thematic analysis approach. Journal of Health Literacy, 4(4), 18–29. https://doi.org/10.22038/JHL.2019.43878.1085

Green, R. A., Whitburn, L. Y., Zacharias, A., Byrne, G., & Hughes, D. L. (2018). The relationship between student engagement with online content and achievement in a blended learning anatomy course. Anatomical Sciences Education, 11(5),

471–477. https://doi.org/10.1002/ase.1761

Greene, J. A., Seung, B. Y., & Copeland, D. Z. (2014). Measuring critical components of digital literacy and their relationships with learning. Computers & Education, 76, 55–69. https://doi.org/10.1016/j.compedu.2014.03.008

Harris, L. R., & Brown, G. T. L. (2009). The complexity of teachers' conceptions of assessment: Tensions between the needs of schools and students. Assessment in Education: Principles, Policy & Practice, 16(3), 365–381. https://doi.org/10.1080/09695940903319745

Hattwig, D., Bussert, K., Medaille, A., & Burgess, J. (2013). Visual literacy standards in higher education: New opportunities for libraries and student learning. Portal, 13(1), 61–89. https://doi.org/10.1353/pla.2013.0008

Ikpeze, C. H. (2018). Designing e-books: Enhancing prospective teachers' digital literacy skills. In E. Ortlieb, E. H. Cheek, Jr., & P. Semingson (Eds.), Best practices in teaching digital literacies (pp. 29–42). Emerald Publishing Limited.

Ilyashenko, L. K., Gladkova, M. N., Kutepov, M. M., Vaganova, O. I., & Smirnova, Z. V. (2019). Development of communicative competencies of students in the context of blended learning. Amazonia Investiga, 8(18), 313–322. https://amazoniainvestiga.info/index.php/amazonia/article/view/313

Joyce, B., Calhoun, E., & Hopkins, D. (2008). Models of learning, tools for teaching. McGraw-Hill Education.

Joyce, B., Weil, M., & Calhoun, E. (2015). Models of teaching (9th ed.). Person Education.

Kirschner, P., Sweller, J., & Clark, R. E. (2006). Why unguided learning does not work: An analysis of the failure of discovery learning, problem-based learning, experiential learning and inquiry-based learning. Educational Psychologist, 41(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

Lopez Islas, J. R. (2013). Digital literacy and academic success in online education for underprivileged communities: The prep@net case [Doctoral dissertation, University of Texas at Austin]. UT Electronic Theses and Dissertations. http://hdl.handle.net/2152/20948

Mahande, R. D., Malago, J. D., & Hartoto, H. (2021). The prototype of 4Cs-based blended learning content. Journal of Educators Online, 18(1). https://doi.org/10.9743/JEO.2021.18.1.4

Makhmudov, K., Shorakhmetov, S., & Murodkosimov, A. (2020). Computer literacy is a tool to the system of innovative cluster of pedagogical education. European Journal of Research and Reflection in Educational Sciences, 8(5).

Martin, A., & Grudziecki, J. (2006). DigEuLit: Concepts and tools for digital literacy development. Innovation in Teaching and Learning in Information and Computer Sciences, 5(4), 249–267. https://doi.org/10.11120/ital.2006.05040249

McCoach, D. B., Gable, R. K., & Madura, J. P. (2013). Instrument development in the affective domain. Springer. https://doi.org/10.1007/978-1-4614-7135-6

McGuinness, C., & Fulton, C. (2019). Digital literacy in higher education: A case study of student engagement with e-tutorials using blended learning. Journal of Information Technology Education: Innovations in Practice, 18, 1–28. https://doi.org/10.28945/4190

Mery, Y., & Newby, J. (2014). Online by design: The essentials of creating information literacy courses. Rowman & Littlefield.

Meyer, K. R., Hunt, S. K., Megan Hopper, K., Thakkar, K. V, Tsoubakopoulos, V., & Van Hoose, K. J. (2008). Assessing information literacy instruction in the basic communication course. Communication Teacher, 22(1), 22–34. https://doi.org/10.1080/17404620801926925

Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. International Journal of Educational Research Open, 1, 100012. https://doi.org/10.1016/j.ijedro.2020.100012

Napier, N. P., Dekhane, S., & Smith, S. (2011). Transitioning to blended learning: Understanding student and faculty perceptions. Journal of Asynchronous Learning Network, 15(1), 20–32. https://doi.org/10.24059/olj.v15i1.188

Neag, A. (2015). Media literacy and the Hungarian National Core Curriculum–A curate's egg. Journal of Media Literacy Education, 7(1), 35–45. https://doi.org/10.23860/jmle-7-1-4

Nelson, K., Courier, M., & Joseph, G. W. (2011). An investigation of digital literacy needs of students. Journal of Information Systems Education, 22(2), 95–110.

Ozdamar-Keskin, N., Ozata, F. Z., Banar, K., & Royle, K. (2015). Examining digital literacy competences and learning habits of open and distance learners. Contemporary Educational Technology, 6(1), 74–90. https://doi.org/10.30935/cedtech/6140

Qasem, A. A. A., & Nathappa, V. (2016). Teachers'perception towards ICT integration: Professional development through blended learning. Main Issues of Pedagogy and Psychology, 11(2), 20–26. https://doi.org/10.24234/miopap.v11i2.221

Rahmi, U., & Azrul, A. (2019). Diagnosing the quality of the discussions in blended learning: An effort to augment the students' Higher Order Thinking Skills (HOTS). International Journal of Scientific & Technology Research, 8(11), 1124–1127.

Rahmi, U, Syafril, S., & Azrul, A. (2021). Students' expectations for blended learning discussion in higher education. Journal of Physics: Conference Series, 1940(1), 12130. https://doi.org/10.1088/1742-6596/1940/1/012130

Reigeluth, C. M., & An, Y. (2020). Merging the instructional design

process with learner-centered theory: The holistic 4D model. Routledge. https://doi.org/10.4324/9781351117548

Serrano, D. R., Dea Ayuela, M. A., Gonzalez Burgos, E., Serrano Gil, A., & Lalatsa, A. (2019). Technology-enhanced learning in higher education: How to enhance student engagement through blended learning. European Journal of Education, 54(2), 273–286. https://doi.org/10.1111/ejed.12330

Simons, M., Meeus, W., & T'Sas, J. (2017). Measuring media literacy for media education: Development of a questionnaire for teachers' competencies. Journal of Media Literacy Education, 9(1), 99–115. https://doi.org/10.23860/JMLE-2017-9-1-7

Šorgo, A., Bartol, T., Dolničar, D., & Boh Podgornik, B. (2017). Attributes of digital natives as predictors of information literacy in higher education. British Journal of Educational Technology, 48(3), 749–767. https://doi.org/10.1111/bjet.12451

Staker, H., & Horn, M. B. (2012). Classifying K–12 blended learning. Innosight Institute. https://www.christenseninstitute.org/wp-content/uploads/2013/04/Classifying-K-12-blended-learning.pdf

Stokes, S. (2002). Visual literacy in teaching and learning: A literature perspective. Electronic Journal for the Integration of Technology in Education, 1(1), 10–19.

Tang, C. M., & Chaw, L. Y. (2016). Digital literacy: A prerequisite for effective learning in a blended learning environment? Electronic Journal of E-Learning, 14(1), 54–65.

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). Instructional development for training teachers of exceptional children (ED090725). Center for Innnovation in Teaching the Handicapped. Indiana University. ERIC. https://files.eric.ed.gov/fulltext/ED090725.pdf

Tumburku, W. G., Kamba, A. H., Muhammad, S., & Gwandu, Z. L. (2019). Computer literacy and teachers' job performance in secondary schools in Danko-Wasagu Local Government Area, Kebbi State, Nigeria. Journal of Advances in Education and Philosophy, 3(7), 258–263. https://doi.org/10.21276/jaep.2019.3.7.2

Van Joolingen, W. (2004). The PISA framework for assessment of ICT literacy (Powerpoint Presentation). University of Amsterdam. Retrieved from https://oei.org.ar/ibertic/evaluacion/sites/default/files/biblioteca/7_pisa_framework.pdf

Vorholzer, A., & von Aufschnaiter, C. (2019). Guidance in inquiry-based instruction–an attempt to disentangle a manifold construct. International Journal of Science Education, 41(11), 1562–1577. https://doi.org/10.1080/09500693.2019.1616124

Walsh, A. (2015). Playful information literacy: Play and information literacy in higher education. Nordic Journal of Information Literacy in Higher Education, 7(1), 80–94. https://doi.org/10.15845/noril.v7i1.223

Yigit, E. O., & Ozturk, C. (2012). Social studies pre-service teachers' views about technology literacy. Procedia-Social and Behavioral Sciences, 46, 36–40. https://doi.org/10.1016/j.sbspro.2012.05.063