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Crowd Context-Based Learning Process via IoT Wearable Technology to Promote Digital Health Literacy

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Abstract

The crowd context-based learning process via IoT wearable technology [IoTW-driven Crowd context-based learning (CCBL)] is a new learning paradigm that integrates Technological Cybergogical Content Knowledge (TCACK) based on connectivism, cognitive tools and information processing theories to promote digital health literacy. In this study, the IoTW-driven CCBL was designed by incorporating content, cybergogical, and technological elements, which can become a sustainable solution in educational settings during the global COVID-19 pandemic. The researchers collected qualitative data by confirmatory focus groups from 12 experts who hold doctoral degrees or equivalent and have at least 3 years of relevant experience. The results of these studies found that the IoTW-driven CCBL involves three specific learning contents (healthcare, disease prevention and health promotion); five dynamic learning steps (context-aware alerting step; observing and questioning step; social information-seeking step; action step; and self-reflection step as all cognitive tools embedded in IoTW devices help promote all digital health literacy components); and four cognitive tools (notification tool; communication tool; searching tool; and monitoring tool). The IoTW-driven CCBL will allow learners to respond to real-life situations by utilising IoT devices to access, apprehend, appraise and apply health information from digital technologies in daily life for well-being, especially in educational settings.

Keywords: context-based learning, crowd learning, IoT wearable technology, digital health literacy

1. Introduction

The global coronavirus disease 2019 (COVID-19) pandemic has highlighted the urgent need for a digital instructional process in a ubiquitous environment to promote digital health literacy (DHL) for digital citizens (Dadaczynski et al., 2021; Metcalf et al., 2016; Sørensen et al., 2012), which include the following:

1) Health promotion refers to the ability to frequently update oneself on the determinants of health in the social and physical environment, to interpret and extract meaning from information on the determinants of health in the social and physical environment, to interpret and evaluate information about the health determinants in the social and physical environment and to make educated decisions about health factors in the social and physical environment.

2) Disease prevention refers to the ability to obtain information on health risk factors, to comprehend and interpret information on risk factors, to assess and evaluate information on risk factors and to make well-informed decisions about health risk factors.

3) Healthcare refers to the ability to access and obtain medical or clinical information, comprehend medical information, interpret and evaluate medical information, make educated medical decisions and follow medical advice.

The Internet of Things and wearables (IoTW) for health and early case studies concerning IoTW interventions drive this emerging technology domain. It has reflected on significant findings linked to these emerging technologies and use cases, influencing healthcare providers, digital citizens and patients. Thus, technologists having a firm understanding of customer-driven innovation and the actual user benefits of interconnective devices for health can help us engineer better solutions that are more targeted to the triple aim of better, faster and cheaper health solutions (Metcalf et al., 2016).

Crowd context-based learning (CCBL), rooted in a cybergogical way (Daud et al., 2019) in Internet technology adoption, particularly Web 2.0, has allowed people to access a wide range of crowd thoughts and beliefs, allowing for new modes of communication and knowledge construction. In these new contexts, previous methods of

browsing and filtering available data are likely to be inadequate. One of the most well-known network learning theories established for dynamic online learning environments is the connectivism theory. In addition, medical educators are beginning to realise connectivism theory in the digital era (Goldie, 2016).

Typically, the cognitive tools approach from an educational perspective concerning learners, tools and activities; these are all part of an open learning system. This approach helps to clarify the nature of cognitive tools from types of utility tools mainly used in educational settings for creating open learning environments (OLE) (Beaumie & Thomas, 2007).

All UN member states endorsed the 2030 Agenda for Sustainable Development Goals in September 2015, with 17 goals and 169 targets to be achieved in 2030; especially Goal 3: Promote healthy lives and promote well-being, and Goal 4: Enhance inclusive and equitable quality education and promote lifelong learning opportunities for all (Mukarram, 2020).

King Mongkut's University of Technology North Bangkok (KMUTNB) is a higher education institution in Thailand, which focuses on producing industrial teachers, engineers, scientists, architects, technologists and technicians based on KMUTNB's unique identity: creating inventions to innovations according to the needs of the manufacturing, commercial, educational and training sectors.

Consequently, the utilisation of IoTW-driven CCBL can improve digital health literacy. Notwithstanding, since 2020, the COVID-19 pandemic situation has pushed KMUTNB and other educational institutions in Thailand to shift from 'on-site instruction' to 'online instruction' more than ever before, so students need to learn online via multi-screen media for many hours per day. It may negatively affect many students' physical, social and mental health. This research aimed to investigate and evaluate the utility of IoTW-driven CCBL to promote digital health literacy, which is an urgent need in the digital era and especially in the educational setting during the COVID-19 pandemic situation.

2. Research questions

The following research questions have been formulated:

Q1: What are the components as a learning outcome of digital health literacy; what should such core components consist of?
Q2: What are the learning contents as a meaningful learning issue for IoTW-Driven CCBL to promote digital health literacy; what should such specific learning contents consist of?
Q3: What are the learning steps as a cybergogical process for IoTW-Driven CCBL to promote digital health literacy; what should such learning steps consist of?
Q4: What are the cognitive tools as a technological element for IoTW-Driven CCBL to promote digital health literacy; what should such cognitive tools consist of?
Q5: How can IoTW-driven CCBL promote digital health literacy?

3. Method

With IoTW-driven CCBL rooted in cybergogical learning (Daud et al., 2019), we have been investigating, designing and evaluating the utility of the IoTW-driven CCBL to promote digital health literacy. Based on considering the technological cybergogical content knowledge adapted from the TPACK framework (Tao et al., 2017) by researchers, modified from pedagogical to cybergogical due to several studies (Beaumie & Thomas, 2007; Daud et al., 2019; Goldie, 2016), we found that the learning styles of people of all ages in the digital era changed from a pedagogical to a cybergogical way. It is more about a learner's active participation in self-directed learning in OLE than it is about the roles of teachers passing on knowledge to learners. Moreover, connectivism (Goldie, 2016), cognitive tools (Beaumie & Thomas, 2007) and information processing theories (Khalil & Elkhider, 2016; Komatsu, Watanabe, & Fukuchi, 2021) have been applied in the design and constructive alignment (Paskevicius, 2017) of IoTW-Driven CCBL to promote digital health literacy. The research was carried out in accordance with the following five research questions.

Q1: What are the components as a learning outcome of digital health literacy; what should such core components consist of?

The researchers gathered qualitative data for the first research question by conducting a literature review of the research articles related to digital health literacy in the ThaiJO, PubMed, Scopus and Web of Science databases, and then analysed and synthesised the core components of digital health literacy, as shown in Table 1.

Table 1. Synthesis of core components of digital health literacy

Literature review	Core components of digital health literacy			
	Accessibility	Apprehensibility	Appraisability	Applicability
Norman and Skinner (2006)	✓	✓	✓	✓
Pleasant, McKinney, and Rikard (2011)	✓	✓	✓	✓
Vaart et al. (2013)	✓	✓	✓	✓
Flash Eurobarometer 404 (2014)	✓	✓	✓	✓
Shiferaw et al. (2020)	✓	✓	✓	✓
Jean, Taylor, and Kodama (2017)	✓	✓	✓	✓
Vaart and Drossaert (2017)	✓	✓	✓	✓
Broucke and Vandenbosch (2018)	✓	✓	✓	✓
Vrdelja et al. (2021)	✓	✓	✓	✓
Giudice (2017)	✓	✓	✓	✓
Park and Kwon (2021)	✓	✓	✓	✓
Kayser et al. (2018)	✓	✓	✓	✓

The qualitative data shown in Table 1 indicates that the core components of digital health literacy are divided into four core components, as follows: accessibility, which refers to the ability to seek, find and obtain digital health information; apprehensibility, which refers to the ability to understand or comprehend the digital health information that is accessed; appraisability, which refers to the ability to interpret, filter, judge and appraise or evaluate the digital health information that has been accessed; and applicability, which refers to the ability to communicate, use or apply digital information to make a decision to maintain and improve health.

Q2: What are the learning contents as a meaningful learning issue for IoTW-Driven CCBL to promote digital health literacy; what should such specific learning contents consist of?

For the second research question, the researchers collected qualitative data through an in-depth interview (Goldman & Swayze, 2012) with four health education experts who hold doctoral degrees, and there are research papers published in internationally recognised online databases (Ministry of Education, 2019) to analyse and synthesise the specific learning content to promote digital health literacy, as shown in Table 2.

Table 2. Synthesis of specific learning content to promote digital health literacy

Specific learning content	Expert 1	Expert 2	Expert 3	Expert 4
1. Healthcare content		✓	✓	✓
2. Disease prevention content	✓	✓	✓	✓
3. Health promotion content	✓	✓	✓	✓

The qualitative data shown in Table 2 indicates that the specific learning contents of digital health literacy are divided into the following three scopes: healthcare content; disease prevention content; and health promotion content.

Q3: What are the learning steps as a cybergogical process for IoTW-Driven CCBL to promote digital health literacy; what should such learning steps consist of?

For the third research question, the researchers collected qualitative data by conducting a literature review of educational technology trend reports and research articles related to digital health literacy in the ThaiJO, PubMed, Scopus and Web of Science databases, and then analysed and synthesised CCBL to promote digital health literacy, as shown in Table 3.

Table 3. Synthesis of learning steps to promote digital health literacy

	Literature review	Crowd Context-Based Learning (CCBL)				
		Step 1 Context-Aware Alerting	Step 2 Observing and Questioning	Step 3 Social Information-Seeking	Step 4 Action	Step 5 Self-Reflection
Context-based learning	Jong (2008)	✓	✓	✓		✓
	Pramchoo, Sreethunyoo, and Meesuk (2010)	✓	✓	✓	✓	
	Vaino, Holbrook, and Rannikmäe (2012)	✓	✓	✓	✓	✓
	Kuang-Chao, Szu-Chun, and Kuen-Yi (2015)	✓	✓	✓	✓	✓
	Deveci and Karteri (2020)	✓	✓	✓	✓	✓
	Dori et al. (2018)	✓	✓	✓	✓	✓
	Hasanpour-Dehkordi and Solati (2016)	✓	✓	✓		✓
	Avargil, Herscovitz, and Dori (2012)	✓	✓	✓	✓	✓
	Puplampu and Ross (2017)	✓	✓	✓	✓	✓
	Boonsathit, Panprueksa, and Chaiprasert (2020)	✓	✓	✓	✓	
Crowd-based learning	Sharples et al. (2016)	✓	✓	✓		✓
	Wong (2017)	✓	✓	✓		✓
	Heffernan et al. (2016)	✓	✓	✓		✓
	Ferguson (2017)		✓	✓	✓	✓
	Hildebrand, Ahumada, and Watson (2013)	✓	✓	✓		✓
	Rubenstein (2013)		✓	✓		✓
	Tang et al. (2016)		✓	✓		✓
	Tucker et al. (2019)		✓	✓	✓	✓
	Wu et al. (2019)	✓	✓	✓	✓	✓
	Puritat (2019)	✓	✓	✓		✓
	Wang et al. (2020)	✓	✓	✓	✓	✓

The qualitative data shown in Table 3 indicates that the dynamic learning steps for IoTW-driven CCBL to promote digital health literacy are divided into the following five steps: context-aware alerting; observing and questioning; social information-seeking; action; and self-reflection.

Q4: What are the cognitive tools as a technological element for IoTW-Driven CCBL to promote digital health literacy; what should such cognitive tools consist of?

For the fourth research question, the researchers collected qualitative data through an in-depth interview (Goldman & Swayze, 2012) with four cognitive technology experts who hold doctoral degrees, and there are research papers published in internationally recognised online databases (Ministry of Education, 2019) to analyse and synthesise the cognitive tools embedded in IoTW to promote digital health literacy, as shown in Table 4.

Table 4. Synthesis of cognitive tools to promote digital health literacy

Cognitive tools embedded in wearable IoTs	Expert 1	Expert 2	Expert 3	Expert 4
Digital health notification tools	✓	✓		✓
Digital health communication tools	✓	✓	✓	✓
Digital health searching tools	✓	✓	✓	✓
Digital health monitoring tools	✓	✓	✓	✓

The qualitative data shown in Table 4 indicates that the cognitive tools embedded in IoT-wearable technology for IoTW-Driven CCBL to promote digital health literacy are divided into the following four tools: digital health

notification tools; digital health communication tools; digital health searching tools; and digital health monitoring tools.

Q5: How can IoTW-driven CCBL promote digital health literacy?

For the fifth research question, the researchers collected qualitative data through Exploratory Focus Groups (EFGs) (Tremblay et al., 2010) from 12 experts who hold doctoral degrees or equivalent and have at least 3 years of relevant experience. This question focuses on the IoTW-driven CCBL's constructive alignment to promote digital health literacy, as shown in Table 5.

Table 5. The constructive alignment of the IoTW-driven CCBL to promote digital health literacy

How an IoTW-Driven CCBL to promote digital health literacy			
CCBL	IoTW-Driven	Cognitive Processes	Digital Health Literacy (DHL)
1. Context-aware alerting	[✓]Digital health notification tool [ ]Digital health communication tool [ ]Digital health searching tool [ ]Digital health monitoring tool	[✓]Attention [ ]Perception [ ]Comprehension [ ]Decision-making [ ]Metacognition	[✓]DHL1:Accessibility [ ]DHL2:Apprehensibility [ ]DHL3:Appraisability [ ]DHL4:Applicability
2. Observing and questioning	[ ]Digital health notification tool [✓]Digital health communication tool [ ]Digital health searching tool [ ]Digital health monitoring tool	[ ]Attention [✓]Perception [ ]Comprehension [ ]Decision-making [ ]Metacognition	[✓]DHL1:Accessibility [✓]DHL2:Apprehensibility [ ]DHL3:Appraisability [ ]DHL4:Applicability
3. Social information-seeking	[ ]Digital health notification tool [ ]Digital health communication tool [✓]Digital health searching tool [ ]Digital health monitoring tool	[ ]Attention [ ]Perception [✓]Comprehension [ ]Decision-making [ ]Metacognition	[✓]DHL1:Accessibility [✓]DHL2:Apprehensibility [✓]DHL3:Appraisability [ ]DHL4:Applicability
4. Action	[ ]Digital health notification tool [ ]Digital health communication tool [ ]Digital health searching tool [✓]Digital health monitoring tool	[ ]Attention [ ]Perception [ ]Comprehension [✓]Decision-making [ ]Metacognition	[✓]DHL1:Accessibility [✓]DHL2:Apprehensibility [✓]DHL3:Appraisability [✓]DHL4:Applicability
5. Self-reflection	[✓]Digital health notification tool [✓]Digital health communication tool [✓]Digital health searching tool [✓]Digital health monitoring tool	[✓]Attention [✓]Perception [✓]Comprehension [✓]Decision-making [✓]Metacognition	[✓]DHL1:Accessibility [✓]DHL2:Apprehensibility [✓]DHL3:Appraisability [✓]DHL4:Applicability

The qualitative data shown in Table 5 indicates that the dynamic learning steps for IoTW-driven CCBL that can promote digital health literacy are divided into the following five steps: context-aware alerting steps can help to improve accessibility; observing and questioning steps aid in accessibility, apprehensibility or comprehension; social information-seeking activities can help to improve accessibility, comprehension and appraisal; action steps are an aid in the promotion of all aspects of digital health literacy; and self-reflection steps are an aid in the promotion of all aspects of digital health literacy.

4. Results

The IoTW-driven CCBL to promote DHL has five dynamic learning steps: context-aware alerting; observing and questioning; social information-seeking; action; and self-reflection. These are explained below.

4.1 Context-Aware Alerting

Context-aware alerting is the process of enabling learners to meaningfully receive learning. In this process, each learner will be notified digitally of the contextual learning based on adaptable biological clocks from digital health information notification tools via IoT-based wearable user interfaces that enable the learners' cognitive processing at their level of attention. However, each learner's learning process will start when they hear or see meaningful notifications. This step helps promote accessibility.

Figure 1. Context-aware alerting step

4.2 Observing and Questioning

Observing and questioning is the process after learners have paid attention to the notifications. In this process, each learner will use their senses to interact with the meaningful content from digital health information communication tools via IoT-based wearable user interfaces that enable the learners' cognitive processing at their level of perception. However, each learner's learning process will start when the learner encodes and decodes meaningful content, which causes interest, doubt or meaningful questions that need answers about health education. This step helps promote accessibility and apprehensibility.

Figure 2. Observing and questioning step

4.3 Social Information-Seeking

Social information-seeking is the process after each learner realises that they have insufficient knowledge and potential to respond to health promotion, disease prevention and healthcare. However, each learner's learning process will start when they encode and decode meaningful health information from quality digital resources, social networking and crowd-sourcing platforms. In this process, learners will search for the information they need from digital health information searching tools via IoT-based wearable user interfaces that enable the learners' cognitive processing at their level of comprehension. This step helps promote accessibility, apprehensibility and appraisability.

Figure 3. Social information-seeking step

4.4 Action

Action is the process after learners' thorough understanding of the health information. However, each learner's learning process will start with the decision to make health behaviour changes (e.g., dietary choices, movement, exercise, emotion and stress management, sleep etc.). Through this process, learners will be able to apply information and knowledge to healthy behaviours. In addition, learners will be supported by digital health information monitoring tools via IoT-based wearable user interfaces that enable their cognitive processing at their decision-making level. This step helps promote all DHL components.

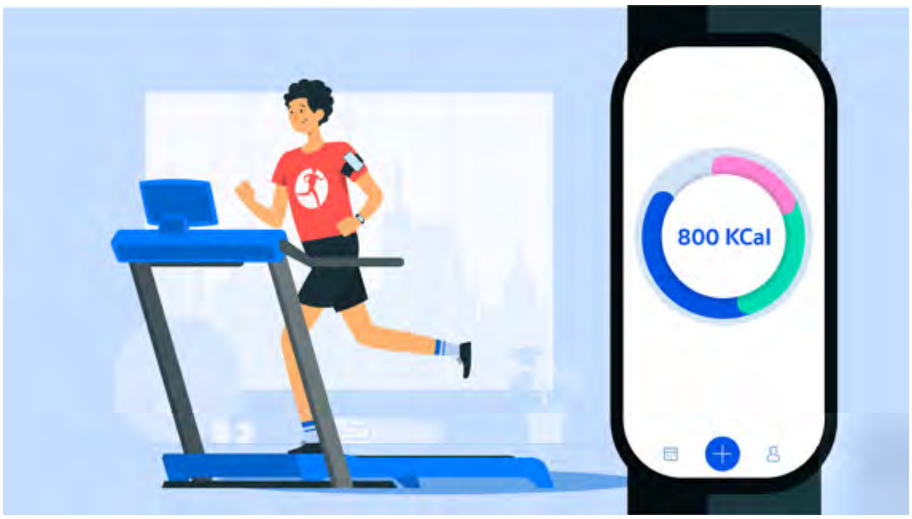

Figure 4. Action step

4.5 Self-Reflection

Self-reflection is the dynamic process connected to all the above-mentioned processes. In this process, learners will engage in reflective thinking based on their digital health status and behaviours. Furthermore, learners will be supported by all the above-mentioned cognitive tools via IoT-based wearable user interfaces that enable the learners' cognitive processing at their level of metacognition. However, this automated learning process depends on the learner's commitment to learning based on motivation, profile and self-management powered by the IoTW-driven CCBL. This step helps promote all DHL components.

Figure 5. Self-reflection step

The researchers used the experts' judgment method to evaluate the utility of the IoTW-driven CCBL to promote DHL (Tremblay et al., 2010) by collecting and analysing quantitative data from 12 experts with doctoral degrees or equivalent experience and at least 3 years of relevant experience, as shown in Table 6.

Table 6. The results of evaluating the utility of IoTW-driven CCBL to promote digital health literacy

Evaluation items	Mean	SD	Level of agreement
1. Context-aware alerting	5.00	0.00	Strongly agree
2. Observing and questioning	4.92	0.28	Strongly agree
3. Social information-seeking	5.00	0.00	Strongly agree
4. Action	4.67	0.62	Strongly agree
5. Self-reflection	5.00	0.00	Strongly agree
Overall mean	4.92	0.18	Strongly agree

The quantitative data shown in Table 6 indicates that the experts strongly agreed overall in terms of the utility of IoTW-driven CCBL to promote digital health literacy (mean = 4.92, SD = 0.18). Most experts agreed that context-aware alerting, social information-seeking and self-reflection help promote digital health literacy (mean = 5.00, SD = 0.00), followed by observing and questioning (mean = 4.92, SD = 0.28). This information demonstrated that the experts agreed that action was the step that was rated at the lowest level (mean = 4.67, SD = 0.62). In addition, the qualitative data from some experts has suggested calling these five learning processes 'the COSAS learning processes', where 'COSAS' is a Spanish word meaning 'things' (João, Souza, & Serralvo, 2020) that includes sensors, software and other technologies to connect and exchange data with smart devices via the Internet (Songsom, Nilsook, & Wannapiroon, 2019).

5. Discussion

The crowd context-based learning process via IoT-wearable technology (IoTW-driven CCBL) is a new learning paradigm to promote digital health literacy. This paradigm shifts from the 'pedagogical way' to the 'cybergogical way'. It concerns a person's active engagement with dynamic, self-directed learning in OLE more than transferring knowledge from teachers to learners in the linear learning process in classroom learning environments. In addition, connectivism, cognitive tools and information processing theories have been applied in the design and constructive alignment of IoTW-driven CCBL to promote digital health literacy. Notwithstanding, the researchers have collected and analysed both qualitative and quantitative data to answer this critical research question: 'How can IoTW-driven CCBL promote digital health literacy?', which is considered to create a new body of knowledge concerning digital-technology-enhanced learning to promote digital health literacy urgently needed in the digital era. The IoTW-DRIVEN CCBL to promote digital health literacy consists of the following five dynamic steps:

1) Context-aware alerting through digital health information notification tools embedded in IoTW devices helps

promote accessibility.

2) Observing and questioning through digital health information communication tools embedded in IoTW devices help promote accessibility and apprehensibility.

3) Social information-seeking through digital health information searching tools embedded in IoTW devices helps promote accessibility, apprehensibility and appraisability.

4) Action through digital health information monitoring tools embedded in IoTW devices helps promote all digital health literacy components.

5) Self-reflection through all the cognitive tools embedded in IoTW devices helps promote all digital health literacy components.

Moreover, the results of evaluating the utility of IoTW-driven CCBL in order to promote digital health literacy by experts' judgment found the overall utility rating at a strongly agreed level, potentially signifying that the IoTW-driven CCBL could be recommended for utilisation to promote digital health literacy needed for the digital era.

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