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Hybrid Teaching Using Problem-Based Learning to Promote Self-Directed Learning Abilities of Students during the COVID-19 Pandemic

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Abstract. This study aims to 1) investigate the self-directed learning (SDL) abilities and factors influencing SDL among undergraduate students, and 2) examine the effects of hybrid teaching using problem-based learning in promoting self-directed learning abilities. The study is divided into two phases. The first phase involves analyzing self-directed learning abilities and factors influencing SDL among students in Thailand Universities, with a sample group of 326 individuals. The research tool in Phase 1 was a Self-Directed Learning evaluation form. The findings reveal that students possess high levels of self-directed learning abilities in all aspects. Furthermore, all factors significantly impacted SDL, with the highest influence in the utilization of information technology. The statistical regression model is represented by $\hat{Y} = 1.542 + 0.115X_1 + 0.088X_2 + 0.303X_3$, indicating that the model can predict the dependent variable with an accuracy of 34%. In the second phase, the effects of the approach in promoting self-directed learning abilities were explored out with an experimental sample group of 17 students, enrolled in the Database Systems for Technology and Computer Innovation course. The main research tools for Phase 2 included (1) a Self-Directed Learning evaluation form, (2) an achievement test, and (3) a questionnaire. The findings revealed the highest level in all aspects, and students who learned through the approach demonstrated higher self-directed learning abilities after the course. Additionally, their post-course learning outcomes were significantly higher than their pre-course outcomes, with statistical significance at the 0.01 level. Students expressed a favorable perception toward the learning approach.

Keywords: COVID-19 Pandemic; Hybrid Teaching; Problem-Based Learning; Self-Directed Learning

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1. Introduction

The recent COVID-19 crisis has had significant and ongoing impact on the activities and learning systems of undergraduate students. It has necessitated a shift to online learning in some cases and traditional classroom learning in others. One of the challenges encountered by students in online learning is the lack of direct supervision and facilitation of learning, as compared to learning in a physical classroom. Students are unable to effectively control their own learning, as observed through their learning behaviors and academic performance, which has resulted in a learning loss (Equitable Education Research Institute [EEFI], 2022).

Therefore, creating an effective learning environment and the cultivation of lifelong learning skills are part of self-directed learning, which is an essential soft skill in the present day. In addition, hybrid learning is taken into account as an effective new normal approach during the Covid pandemic in educational management, combining classroom-based learning (with physical distancing) and online learning. The approach is gaining popularity as it aims to provide students with an appropriate learning environment and achieve the highest educational outcomes through the utilization of modern tools and multimedia. Tsoi and Goh (2008) discussed the four components of hybrid learning: (1) transformation involves changing the traditional general teaching and learning methods to ones that emphasize experiential learning; (2) experience creation is a crucial component that focuses on enabling learners to observe, analyze, and learn independently; (3) practice is an important element that bridges experience creation and integration, emphasizing the development of ideas derived from learners' own learning experiences; and (4) integration emphasizes the application of concepts according to learners' needs (Tsoi & Goh, 2008).

Designing hybrid learning activities involves integrating online learning, where students have the flexibility to access learning materials anytime and anywhere, and online classroom teaching, where students and teachers interact through video conference applications like Google Meet, resembling synchronous learning activities in a virtual environment (MicroTek, 2017; Scheiderer, 2021; Tungchityuengyong, 2022). Hybrid teaching can cater to students with different learning styles, provide opportunities for self-directed learning based on their preferred time, location, and convenience, facilitate easy connectivity and coordination, engage and stimulate students' interest, and enhance the effectiveness of their learning outcomes.

Self-directed learning (SDL), as stated in Mingsiritham (2009), naturally arises from voluntary learning without coercion, thus discipline and responsibility are essential in order to bring about meaningful learning experiences and cultivate a lifelong learning culture. Effective and sustainable learning is achieved through self-directed learning, as it enhances learners' motivation, enables them to work at their own ability and pace, and allows them to choose learning content and set goals based on their experiences and personal needs (PPTV, 2022). Consequently, learners experience continuous learning development. This concept aligns with lifelong learning (Donald, 1995). Self-directed learning empowers individuals to

control their own learning, comprehend textbook content independently, and facilitate the synthesis of key concepts. Moreover, it enables learners to solve problems, reason critically, and engage in learning activities. Larisey (1997, as cited in Phodong & Jarujit, 2022) and Borich (2000) emphasize the increasing importance of self-directed learning, as learners will be required to take greater responsibility for their learning in the future. Thus, it becomes essential to cultivate learners' self-directed learning abilities and assess their readiness for learning to enhance their self-responsibility in the learning process.

Problem-based learning (PBL) is an instructional approach that aims to create direct learning experiences by emphasizing hands-on activities, critical thinking development, problem-solving situations, learning planning, and directed learning. PBL also motivates learners and places them at the center of the learning process. In the PBL teaching model, learners engage with the content by attempting to find open-ended solutions to problems (Phungsuk et al., 2017). This approach fosters motivation and enhances self-directed inquiry skills, problem-solving abilities, and clear communication skills. Additionally, it facilitates teamwork and the evaluation of research resources and promotes lifelong learning (Duch et al., 2001) as well as helping to promote the acceptance of different opinions by incorporating collaborative group work and a learner-centered approach. It is a learning method that stimulates learners to think, analyze, search, and integrate new knowledge relevant to real-life situations (Haryani et al., 2018). Moreover, PBL stimulates students' interest in learning within a new environment (Susanti et al., 2020), wherein learners may not necessarily need prior knowledge or a foundational understanding of the subject matter. Barrows (2000) and Evensen and Hmelo (2000) have stated that PBL is related to constructivist learning, which is rooted in the learning theories of Piaget and Vygotsky. Constructivism views learning as an intellectual developmental process in which learners actively construct knowledge. This process of occurs through learners' interactions with the environment and their assimilation and accommodation of new experiences, ultimately resulting in the adaptation of intellectual structures to fit new experiences.

During the Covid pandemic, online learning was a new alternative for classroom instruction in Thailand. However, internet coverage was not accessible in all rural areas. The idea of hybrid learning is, therefore, seemingly an appropriate choice for Thai education to bridge the gap (Ruangsri et al., 2021). Since the online learning part was reliable heavily on students' own learning control, incorporation of self-directed learning also serves as a support tool for fulfilling successful learning setting.

The aforementioned teaching and learning format have been adjusted to align with the current global situation. Universities have implemented a hybrid teaching approach that incorporates online instruction; however, instructors face challenges in maintaining students' focus and the lack of self-directed learning to acquire additional knowledge. As these questions are directed at teaching, the first research question is on how students can gain self-directed learning and its influential factors and second question on how to develop a problem-based

hybrid teaching with the by-product of self-directed skill enhancement. Therefore, the study has the aims of (1) the investigation on to what extent the students can promote their self-directed learning and the influential factors, (2) the examination of the effectiveness of hybrid teaching using problem-based learning. As for a reason, teaching through PBL is one of the plausible approaches enabling learners to acquire self-directed learning. Employing problem-solving methods as a foundation, the design and development of a hybrid teaching model can be enhanced to foster self-directed learning in the Information Technology and Digital Innovation course. Through experimentation and instructional management, it is essential to examine whether this approach can effectively enhance students' ability to engage in self-directed learning.

2. Literature Review

2.1 Hybrid Learning During the COVID-19 Pandemic

Following the COVID-19 pandemic, the traditional teaching approach proved inadequate to meet the educational demands of the current situation. As a result, new teaching approaches have emerged, leveraging technology to facilitate the teaching and learning processes. Examples include online classes with consideration on fostering analytical thinking skills, communication skills, adoption of modern technology, and self-directed learning in order to bring about effective learning and new knowledge.

Hybrid learning is a versatile and adaptable teaching format that combines various learning methods through integration of both offline and online learning methods (MicroTek, 2017). It involves simultaneous learning activities conducted both in real-time, such as live-streamed classes, and recorded online class together with onsite classrooms, thereby exemplifying synchronous learning (Finol, 2020). The hybrid learning experience resembles authentic classroom activities but in a simulated environment (Scheiderer, 2021). Additionally, through flexible and easily accessible platforms such as smartphones, online learning is accessible from anywhere, which characterizes asynchronous learning (Finol, 2020). Learners have the freedom to schedule their learning activities and access resources at their own pace, even retrospectively (Tungchityuengyong, 2022). Hybrid learning combines the strengths and beneficial aspects of various learning modalities, encompassing both classroom-based and online learning through internet-based technologies (Driesen, 2016; Garnham & Kaleta, 2002; Ossiannilsson, 2017). This instructional approach fosters challenging and personalized learning experiences, catering to individual learners' needs and enabling the enhancement of their self-directed learning abilities (Carman, 2002). Hybrid learning systems emphasize interactivity and align with the objective of enhancing the effectiveness and efficiency of teaching and learning processes (Yaso, 2013).

Hybrid learning, as a teaching approach, leverages the advantages of communication technology, enabling learners to engage in more convenient interactions and discussions with instructors. Online classes allow learners and teachers to participate from any location without the need to physically be present at the school every day. This reduces travel time and expenses, while also promoting social distancing and reducing congestion within educational

institutions, which are important measures in preventing the spread of the ongoing COVID-19 pandemic. Simultaneously, this learning format provides opportunities for learners to meet and engage in collaborative learning activities in the classroom. Although the in-class learning time may be reduced, the focus is placed on interactive learning activities, skill development, and summarizing lessons to enhance learners' understanding (Funchian, 2021).

Hybrid learning is a learner-centric instructional approach that enhances the effectiveness of teaching and learning. It is a blended learning format that leverages the advantages of both online teaching and offline examinations. This allows for diverse learner access and aligns with the evolving circumstances of the COVID-19 pandemic or unforeseen future situations. Therefore, instructors should be prepared to adapt to unexpected scenarios while keeping up with the fast-evolving technological landscape. Furthermore, the integration of various learning management strategies and their alignment with different learning contexts should be considered to maximize the efficiency and effectiveness of teaching and learning. Thus, a well-designed hybrid learning approach should cater to the diverse learning styles of learners, capturing and stimulating their interests in learning, while providing them with the flexibility to learn at their own convenience, time, and preferred locations, thus responding to the demands of the new normal lifestyle.

2.2 Problem-Based Learning as a Promoter of Self-Directed Learning

PBL is an instructional approach that emphasizes self-directed learning, utilizing problems as stimuli to ignite learners' desire to explore and seek knowledge (Barrows, 2000). It involves the learners themselves in the process of problem-solving (Duch et al., 2001). The use of problem situations stimulates learners to seek knowledge in order to solve those problems (Office of the Education Council [OEC], 2007). This approach fosters collaborative group work, facilitating knowledge exchange and emphasizing the development of various skills, which can be applied to real problem-solving scenarios. PBL encourages learners to acquire skills in researching information from various learning sources, working collaboratively in teams, and learning to be effective leaders and followers. Learners also have the opportunity to exchange experiences and deepen their understanding by sharing their thoughts and opinions (Imchit, 2013). The focus is on developing learning skills rather than simply acquiring knowledge, resulting in learners engaging with the content and developing problem-solving skills on their own (Edens, 2000).

The process of PBL, based on the use of problems, typically consists of five steps (Hmelo & Lin, 2000; OFC, 2007; Tan & Marincovich, 2003; Weir, 1974) as follows: step 1: problem identification, which refers to investigation and identification of the problems; step 2: problem analysis, which refers to analysis of the causes and sources of the problems; step 3: planning and conducting research which refers to a plan of how to conduct the research; step 4: selecting problem-solving approaches which refers to the experimental teaching approach; and step 5: evaluating learning which refers to the measurement of the success of the learning outcomes. To recap, PBL is an instructional approach in which learners engage with content by actively seeking solutions to open-ended problems (Phungsuk et

al., 2017). It enhances motivation for learning and develops self-directed inquiry skills and also fosters problem-solving skills and encourages learners to apply knowledge gained from their studies to solve real-world problems, thereby promoting critical thinking, reasoning, analysis, and accepting others' perspectives. By utilizing collaborative group work processes, PBL improves learning efficiency and cultivates a learning environment where learners take charge of their own learning (self-directed learning).

2.3 Self-directed Learning

Self-directed learning is a pathway that aims to develop learners who possess the knowledge and readiness to continuously develop themselves. It is a crucial soft skill for learners to maximize their learning effectiveness. It is a personalized learning process that empowers individuals to have the ability to plan their actions and evaluate their learning outcomes. It begins with setting learning goals, seeking support, identifying sources of knowledge, utilizing educational materials, and assessing one's own learning progress. Therefore, it is essential to enable learners to enhance their learning capabilities, as they are able to plan, execute, and evaluate their learning independently. This leads to a continuous learning process, even beyond the confines of the traditional classroom or formal education, and equips learners with lifelong learning skills. Hence, educational management should focus on fostering learners' self-directed learning skills, nurturing their ability to seek knowledge and stay informed about various events and cultivating a love for learning. This will serve as a foundation for their higher-level education. Knowles (1975) and Starfish Academy (2022) mentioned that self-directed learning is a skill that every child should possess for future success, as it enables them to utilize the knowledge available to them effectively. The more proficient learners become in self-directed learning, the greater their chances of achieving success. To elaborate further, self-directed learning has four key benefits:(1) serving learners' needs and satisfaction, (2) promoting learning engagement, freedom, and independence, (3) exhibiting flexibility and learning autonomy, and (4) enabling a lifelong learning.

According to Borich (2000), self-directed learning is crucial as it enables learners to take control of their own learning, understand textbook content independently, and summarize the key concepts. It also helps learners develop problem-solving skills, reasoning abilities, and critical thinking in the learning process. Additionally, Knowles (1975) emphasized the importance of self-directed learning by stating that learners who engage in such an approach achieve better learning outcomes compared to those who rely solely on instructors for knowledge. Self-directed learners approach learning with intentionality, motivation, and the ability to effectively utilize the benefits of learning. Furthermore, learners' development aligns with principles of psychology and natural processes, as they transition from dependency to increased self-reliance and responsibility. Self-directed learners also enhance their learning abilities to adapt to new systems and thrive in a society characterized by constant change. Therefore, self-directed learning is crucial and necessary for individuals to prepare for and adapt to current and future changes. For instance, the COVID-19 pandemic has emphasized the importance of self-directed learning as a

foundation for acquiring enduring skills. In brief, self-directed learning empowers learners to take control of their learning, seek relevant knowledge, and navigate challenges sustainably.

The design of teaching and learning that focuses on promoting self-directed learning is crucial. According to Brockett and Hiemstra (2018), the learning process is the responsibility of learners, who need to engage in planning, executing learning activities, and evaluating their learning processes. Garrison (1997, as cited in Kuawnamchum et al., 2017) stated that self-directed teaching and learning require self-management in order to utilize learning resources, self-monitor, and possess learning motivation. These three aspects are interrelated, with the learning process aiming to enable learners to understand learning strategies. In this process, instructors play the role as facilitators, providing guidance and creating a conducive learning environment (Bolhuis & Voeten, 2001). Currently, instructors can integrate technology into self-directed learning, allowing learners to utilize technology for their learning (Teo et al., 2010; Väljataga & Fiedler, 2009). Teo et al. (2010) summarized the self-directed learning process into three components: goal setting and task analysis, following the planned activities, and evaluating the self-directed learning process. Knowles (1975) described self-directed learning as an approach where learners must organize their learning processes, including diagnosing their learning needs, setting learning objectives, designing learning plans, engaging in learning activities from various sources, and evaluating outcomes.

The concept of self-directed learning management involves customizing individual requirements, growing a sense of self-responsibility, stimulating collaborative learning, and encouraging individual and collaborative assessment. It is expected to become a significant educational paradigm in the future. The management of self-directed learning consists of the five following stages (Knowles, 1975): (1) Self-learning needs analysis, which refers to the perception and ability to analyze one's own learning needs and clearly identify the content or subjects required; (2) Goal setting in learning, which refers to the explicit identification of objectives or targets in learning, characterized by knowledge or activities that can be achieved and measured; (3) Planning and seeking learning resources, which entail developing a personal learning plan that aligns with the identified learning needs and goals; (4) Learning that entails designing learning activities and selecting learning methods that are efficient and align with individual aptitudes and abilities; and (5) Self-assessment of learning, which refers to evaluating one's own learning progress, where the assessment must be in line with the set learning objectives and should determine whether the intended learning goals have been achieved.

2.4 Prevalent Factors toward Self-directed Learning Skills

According to related previous studies, it is conclusive that three significant factors play role as the key to promote self-directed learning skills. The first is information technology (IT), which helps students to be able to find multiple sources of knowledge where they can rely on their own learning and escalate their learning motivation (Lai & Mingyue, 2011). The second factor is problem-solving experience (PS). This is the setting of a learning environment to direct the students

toward their learning goals. It promotes their thought to be more critical and systematic as well as maintains endurance toward their learning achievement (Wisetdonwai, 2022). The last factor is nurturing (NR), which is also one of the prevalent factors. There are many ways for parents to raise their children. The best way to promote self-directed learning is to allow the children to be more free-minded so that they will have more confidence to explore learning on their own. However, the parents also need to provide them proper guidance to lead them to their goals (Hurlock, 1984). Applying these concepts to classroom instruction during the Covid epidemic is worthwhile for a study.

2.5 Context in Thailand during the Covid Pandemic

During the Covid pandemic, the Ministry of Thailand Education established five different teaching approaches to accommodate the unique requirements of each region in the country as they were preparing for the semester's opening. In response to the situation, Thienthong (2021), the Minister of Education, emphasized the need for adaptable instructions and the ministry then devised classroom instructional designs into the following five approaches:

1) On-site learning: this format was suitable for schools with a small number of students, enabling them to maintain strict distancing and adhere to public health measures by wearing face masks. The classroom arrangement allowed for a safe learning environment.
2) On-Air learning: this was implemented through the Distance Learning Foundation System or DLTV. This approach enabled students to participate in classes remotely, accessing educational content through broadcasting.
3) On-Line learning: in this approach, teachers conducted lessons through online platforms, making it possible for students to engage in learning from their own devices.
4) On-demand learning: students could access learning content through applications, allowing them to study at their own pace and convenience.
5) On-hand learning: teachers personally delivered worksheets and learning materials to students at their homes, ensuring continued learning even when physical attendance was not possible.

Throughout this period in Thailand, online learning was implemented and rolled out in classrooms due to the school context suitability. However, the abrupt change to online learning relied heavily on internet access or coverage. Unfortunately, in certain rural areas, weak internet signals posed challenges for some students who faced difficulties learning solely through online means. The concept of conducting an entirely virtual classroom online appeared impractical in the given contexts. Therefore, a viable alternative for the cases was hybrid learning which emerged as a feasible solution, allowing students to engage in both face-to-face and online study (Ruangsri et al., 2021). The students had to rely mainly on taking responsibility in learning for themselves, so facilitating their self-directed learning appeared to be crucial.

3. Research Methodology

The research is a quasi-experimental design. In this section, the details pertaining to research objectives, sample selection, instrumentation, the conceptual

framework, data collection, and data analysis procedures are presented. To begin with, the research objectives are outlined as follows: (1) to examine the presence and prevalence of self-directed learning among students in Thailand and explore the various influential factors that may affect its development; (2) assess the level of students' self-directed learning abilities after conducting an experimental intervention; and (3) to investigate the effectiveness of hybrid teaching using a problem-based learning approach in enhancing students' learning achievement. Two sampling methods include simple random sampling in Phase 1 and purposive sampling in Phase Two. In Phase One, the researchers applied simple random sampling to select a representative sample from the entire population under investigation, which was applied in the study. In Phase 2, the samples were limited to individuals who had enrolled in the Database Systems for Technology and Computer Innovation course. For a comprehensive overview, the conceptual framework is presented in Figure 1.

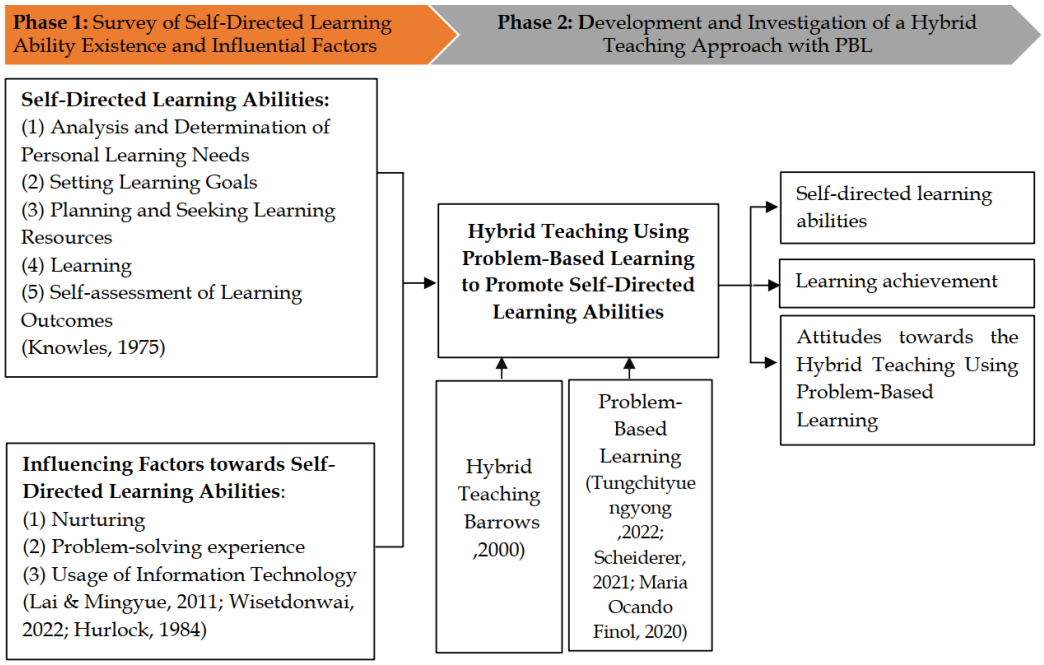

Figure 1: Research Conceptual Framework

Data collection consisted of two phases as mentioned above. Phase 1 involved an investigation of the presence and prevalence of self-directed learning among students in Thailand and explored the various influential factors that may affect its development. Data were collected from a sample group, drawn from simple random sampling, comprised of 326 undergraduate students from four Rajabhat Universities in the western region of Thailand. The sample size was determined and collected using the formula developed by Yamane (1973), out of the total population of 1,747 students who were currently enrolled in the IT relevant programs, from western universities in Thailand. The research instrument employed in this phase was a Self-Directed Learning evaluation form, incorporating a rating scale to assess various potential factors.

It consists of three parts. Part 1 captures general background information of the respondents. Part 2 assesses the factors influencing self-directed learning, consisting of three dimensions: (1) nurturing, (2) problem-solving experiences, and (3) technological competence. These dimensions are measured using a 5-point rating scale. Part 3 measures self-directed learning abilities and consists of five stages: (1) analyzing and determining personal learning needs, (2) setting learning goals, (3) planning and seeking learning resources, (4) learning activities, and (5) self-assessment of learning outcomes. There is a total of 22 factors that will be measured using a five-point rating scale. The measurement for self-directed learning ability was based on the mean value (Best, 1981). Details are as follows:

4.50–5.00	the highest level
3.50–4.49	high level
2.50–3.49	moderate level
1.50–2.49	low level
1.00–1.49	the lowest level

The validity of this measurement instrument was assessed by a panel of seven experts with the IOC of 1.00. Then, it was carried out for a trial with a small group of homogenous 30 students, which resulted in the overall confidence level of 0.93. The relationship assessment between the factors influencing self-directed learning and the levels of self-directed learning were analyzed by using multiple linear regression processed on the correlation levels of each category. Data were collected through an online questionnaire and by the researcher from four Rajabhat Universities in the western region of Thailand. The survey results are categorized and presented in percentage values based on gender, academic year, and educational institutions including Muban Chombueng Rajabhat University (MCRU), Nakhon Pathom Rajabhat University (NPU), Kanchanaburi Rajabhat University (KRU), Phetchaburi Rajabhat University (PRU), as illustrated in Figure 2.

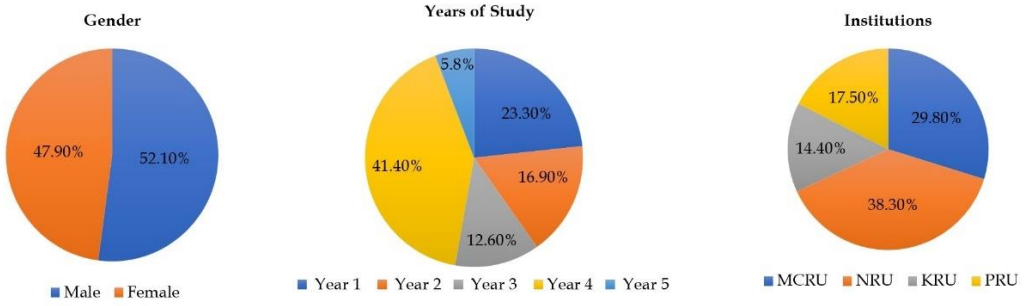

Figure 2: Analysis results shown in percentage values within categorized sample groups based on gender, academic year, and educational institution.

In Phase 1, the data analysis involved employing several statistical measures, including percentage, mean, standard deviation, Pearson's product-moment correlation coefficient, and multiple linear regression. Phase 2 involved the assessment of the level of the students' self-directed learning abilities after conducting an experimental intervention, and the investigation of the effectiveness of hybrid teaching using a problem-based learning approach in enhancing students' learning achievement. Purposive sampling was employed in

this phase, specifically focusing on a targeted group of the individuals who had enrolled in the Database Systems for Technology and Computer Innovation course. The experiment was conducted with a sample group consisting of 17 students majoring in Technology and Computer Innovation. This group of students was the group who were fully equipped with IT skills and readiness for partaking in an online course. The research utilized the following tools: (1) a problem-based hybrid teaching plan; (2) a Self-Directed Learning evaluation form, utilizing a rating scale; (3) online teaching media; (4) a performance measurement for learning achievement; and (5) a questionnaire to gather student feedback on the problem-based hybrid teaching approach. In this phase, the statistics encompassed the measures including mean, standard deviation, Pearson's product-moment correlation coefficient, multiple linear regression, and dependent t-tests. The experiment was conducted in two parts as outlined below:

T_1	X_1	T_2	X_2	T_3

The notation used to represent the different phases is as follows:

- T_1 refers to the pre-test conducted using a traditional teaching method
- X_1 refers to the traditional teaching method
- T_2 refers to the post-test administered after the traditional teaching method has taken place, as well as the pre-test conducted before the implementation of the problem-based hybrid teaching method
- X_2 refers to the problem-based hybrid teaching method.
- T_3 refers to the post-test after the implementation of the problem-based hybrid teaching method.

During Phase 1, a six-week experiment used a traditional teaching method with the sample group of 17 students, taking place in order to compare it with the developed teaching approach. It began with student orientation sessions to explain course details. Students were given a pre-study to assess their knowledge and factors influencing self-directed learning. Then, the traditional teaching method was conducted through video conference sessions according to the instructional design outlined in the learning management plan. Once the planned instructional period was completed, students were given a post-test to measure their learning outcomes and assess their self-directed learning abilities. The collected data were statistically analyzed using commonly used statistical techniques, including measures such as percentage, mean, standard deviation, Pearson's product-moment correlation coefficient, and multiple linear regression. Phase 2 involved an eight-week experimental implementation of the problem-based hybrid teaching method with the same participants group of 17 students. In the five steps teaching, the third step was designed for the students to incorporate self-directed learning skills as to solve the lesson problem. The phase commenced with a detailed explanation of the instructional design for the students. Following the orientation, students were given a pre-study to assess their knowledge and factors influencing self-directed learning before the instructional period.

Then, the problem-based hybrid teaching method was implemented, utilizing the problem-based learning as outlined in the learning management plan. The instruction was delivered through a combination of face-to-face teaching in the classroom via video conference (due to the COVID-19 pandemic situation) and online learning. Upon completion of the experimental period, students were given a post-test to measure their learning outcomes and assess their self-directed learning abilities. The collected data were statistically analyzed using commonly used statistical techniques, including measures such as mean, standard deviation (SD), and a dependent t-test.

4. Results

4.1 Self-directed learning (SDL) abilities of the students

The findings revealed that the overall self-directed learning abilities of the students were at a high level. Setting learning goals had the highest average score of 3.87, followed by learning planning and the search for learning resources with an average score of 3.70. The lowest average score of 3.22 was observed in the area of analyzing and determining one's learning needs, as shown in Table 1.

Table 1: Analysis results for self-directed learning abilities

Assessment List	Mean	SD	Abilities Level
Analysis and Determination of Personal Learning Needs	3.22	0.93	Moderate
Setting Learning Goals	3.87	0.77	High
Planning and Seeking Learning Resources	3.70	0.82	High
Learning	3.51	0.97	High
Self-assessment of Learning Outcomes	3.58	0.91	High
Overall	**3.58**	**0.88**	**High**

4.2 Factors influencing students' SDL

Upon studying the relationships among all of the variables, it was found that all factors possessed a significant positive correlation with self-directed learning. Specifically, the factor related to information technology (IT) has the highest correlation with self-directed learning (r = 0.487), followed by problem-solving experience (PS) (r = 0.365) and nurturing (NR) (r = 0.346), as shown in Table 2.

Table 2: Analysis of the relationship between various factors and self-directed learning abilities

Factors	Nurturing (NR)	Problem-solving experience (PS)	Usage of Information Technology (IT)	Self-directed learning (SDL)
Self-directed learning (SDL)	0.346**	0.365**	0.487**	1

Remark ** Statistically significant at.01 significance level.

After conducting a prognostic study, the factors influencing students' self-directed learning abilities were examined. The independent variables collectively accounted for 34% of the variance in self-directed learning abilities. Furthermore, a multiple regression analysis revealed that all variables significantly contributed

to explaining self-directed learning abilities at a statistical significance level of 0.01. The variable that had the highest explanatory power was the use of information technology, as represented in the prognostic equation: $\hat{Y} = 1.542 + 0.115X_1 + 0.088X_2 + 0.303X_3$. As shown in Table 3.

Table 3: Analysis of Factors Affecting Students' Self-Directed Learning Abilities

Variable	*B*	*SE*	*Beta*	*t-value*	*P value*
Nurturing (x_1)	0.115	0.027	0.214	4.303	.000
Problem-solving experience (x_2)	0.088	0.025	0.175	3.449	.001
Usage of Information Technology (x_3)	0.303	0.035	0.411	8.755	.000
Constant	1.542			9.505	.000
	R = .582 R^2 = .338 SEE = .333 F = 54.682*				

* Statistically significant at the 0.01 significance level.

The results of the prognostic analysis indicated that all factors significantly contributed to the prediction of self-directed learning abilities. Particularly, the variable related to IT usage had the highest significance in predicting such abilities.

4.3 Effects of hybrid teaching using problem-based learning on students' self-directed learning abilities

Regarding the effects of the hybrid teaching approach using problems as a foundation to promote self-directed learning abilities, the findings are shown in the following tables and figures.

Table 4 shows the pre- and post-instructional assessments of students' self-directed learning abilities under a traditional teaching approach. It was found that students had a moderate level of self-directed learning abilities before being exposed to hybrid teaching with an average score of 3.31 out of 5.00. After the exposure to the treatment, which was the hybrid teaching using PBL approach, it was found that students' self-directed learning abilities improved to a moderate level, with an average score of 3.49. The detailed results are shown in Table 4.

Table 4: Analysis results of pre- and post-experimental self-directed learning abilities under a traditional teaching approach

Assessment List	**Pre- experiment**			**Post- experiment**		
	Mean	**SD**	**Level of proficiency**	**Mean**	**SD**	**Level of proficiency**
Analysis and determination of personal learning needs	3.35	0.30	Moderate	3.53	0.37	High
Setting learning goals	3.29	0.33	Moderate	3.47	0.34	Moderate
Planning and seeking learning resources	3.26	0.24	Moderate	3.46	0.35	Moderate
Learning	3.33	0.26	Moderate	3.52	0.31	High
Self-assessment of learning outcomes	3.29	0.20	Moderate	3.45	0.30	Moderate
Overall	**3.31**	**0.21**	Moderate	**3.49**	**0.33**	Moderate

Table 5 shows the results of the self-directed learning abilities of students during pre- and post-experiment of hybrid teaching using PBL as a foundation. Findings revealed that students demonstrated higher levels of self-directed learning abilities overall and in specific aspects after the experiment. The post-experiment scores were higher on average compared to the pre-experiment scores. The aspect with the highest average score was the analysis and determination of personal learning needs, with an average score of 4.37. This was followed by setting learning goals with an average score of 4.35. Planning and seeking learning resources and learning had the same average score (mean = 4.20). The aspect with the lowest average score was self-assessment of learning outcomes, with an average score of 4.07. These comparisons are shown in Table 5 and Figure 5.

Table 5: Analysis results of pre- and post-experimental self-directed learning abilities using a hybrid teaching approach

Assessment List	Pre-experiment			Post-experiment		
	Mean	SD	Level of proficiency	Mean	SD	Level of proficiency
Analysis and determination of personal learning needs	3.53	0.37	High	4.37	0..31	High
Setting learning goals	3.47	0.34	Moderate	4.35	0.28	High
Planning and seeking learning resources	3.46	0.35	Moderate	4.20	0.29	High
Learning	3.52	0.31	High	4.20	0.22	High
Self-assessment of learning outcomes	3.45	0.30	Moderate	4.07	0.20	High
Overall	**3.49**	**0.33**	Moderate	**4.24**	**0.15**	High

The results of the comparison of pre- and post-experimental self-directed learning abilities using hybrid teaching approach are shown as a bar graph in Figure 5.

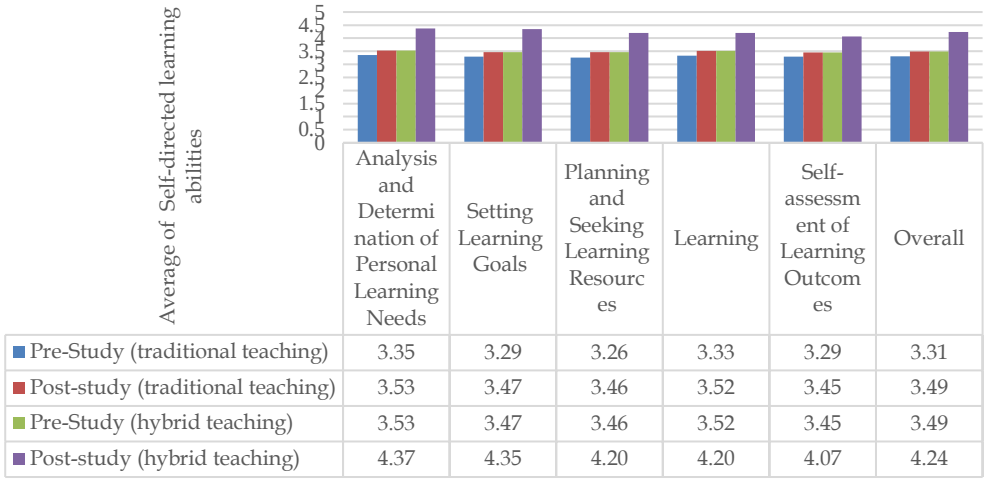

Figure 5: Comparison of pre- and post-experimental self-directed learning abilities using a hybrid teaching approach.

Table 6 shows the results of the comparative analysis of self-directed learning abilities before and after learning. The results indicate that there is no statistically significant difference in overall and specific abilities when comparing the self-directed learning abilities of students before and after traditional teaching. However, when comparing the abilities of students who learned through hybrid teaching using problem-based learning before and after the experiment, a statistically significant difference was found.

Table 6: Comparative analysis of self-directed learning abilities before and after the experiment through traditional teaching and hybrid teaching.

Assessment list	Comparison group	N	Traditional teaching				Hybrid teaching			
			Mean	SD	t	Sig.	Mean	SD	t	Sig.
Analysis and determination of personal learning needs	Pre-study	17	3.35	0.30	0.918	0.37	3..53	0.44	6.752	.000*
	Post-study	17	3.53	0.21			4.37	0.31		
Setting learning goals	Pre-study	17	3.29	0.33	1.414	0.17	3.47	0.29	8.998	.000*
	Post-study	17	3.47	0.29			4.35	0.27		
Planning and seeking learning resources	Pre-study	17	3.26	0.24	1.412	0.18	3.46	0.41	6.614	.000*
	Post-study	17	3.46	0.41			4.20	0.20		
Learning	Pre-study	17	3.33	0.25	0.999	0.332	3.52	0.38	7.436	.000*
	Post-study	17	3.52	0.38			4.20	0.22		
Self-assessment of learning outcomes	Pre-study	17	3.29	0.20	1.074	0.299	3.45	0.30	9.524	.000*
	Post-study	17	3.45	0.30			4.07	0.20		
Overall of self-directed learning	**Pre-study**	17	**3.31**	**0.29**	**1.979**	**0.065**	**3.49**	**0..33**	**10.081**	**0.000***
	Post-study	17	**3.49**	**0.33**			**4.24**	**0.15**		

* Statistically significant at the 0.01 level.

Table 7 present the comparative analysis results of the pre-test and post-test scores of students who were taught through traditional teaching, and then taught with hybrid teaching. Findings revealed a statistically significant increase in academic performance after the experiment at a significance level of 0.01. Similarly, the study found a statistically significant improvement in post-test scores compared to pre-test scores for students who learned through hybrid teaching using PBL, also at a significance level of 0.00. These findings are shown in Table 7.

Table 7: Comparative results of achievement of learning between traditional and hybrid teaching models (within subject design)

Achievement of learning	Sample group	Traditional teaching				Hybrid teaching			
		Mean	SD	t-test	Sig.	Mean	SD	t-test	Sig.
Pre-test	17	7.18	1.29	22.287	.000*	11.23	2.70	16.571	.000*
Post-test	17	13.94	2.14			21.94	3.78		

*Statistically significant at the 0.01 level

The results of the comparison of pre- and post-test achievement scores of traditional and hybrid teaching are shown as a line graph in Figure 6.

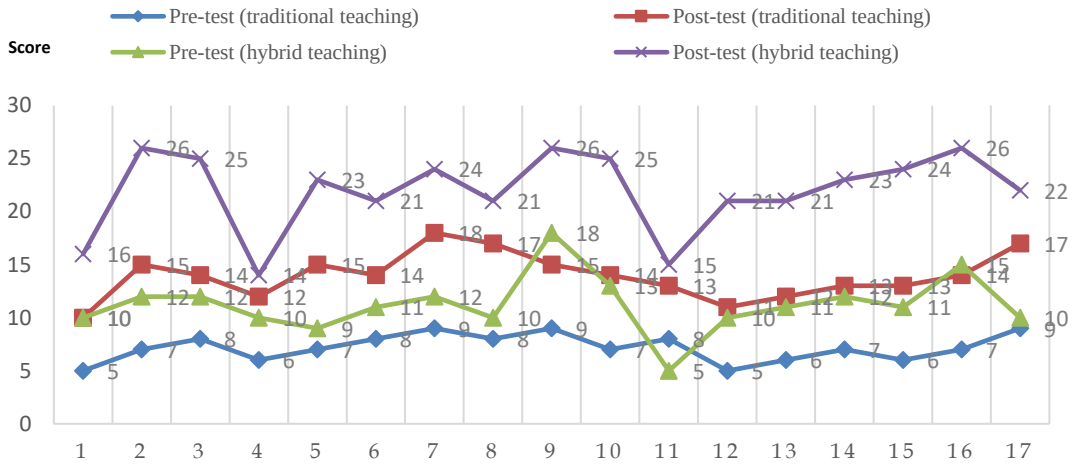

Figure 6: The comparison of pre- and post-test scores of traditional teaching and hybrid teaching formats.

Figure 7 shows the students perceptions toward hybrid teaching using PBL. Overall, students expressed a high level of satisfaction with the hybrid teaching format using PBL, with an average rating of 4.05. In terms of instructional organization, the system's ease of use and accessibility received the highest average rating of 4.29. Following closely behind is the effectiveness and suitability of online and classroom learning assessment formats, with an average rating of 4.24., as illustrated in Figure 7.

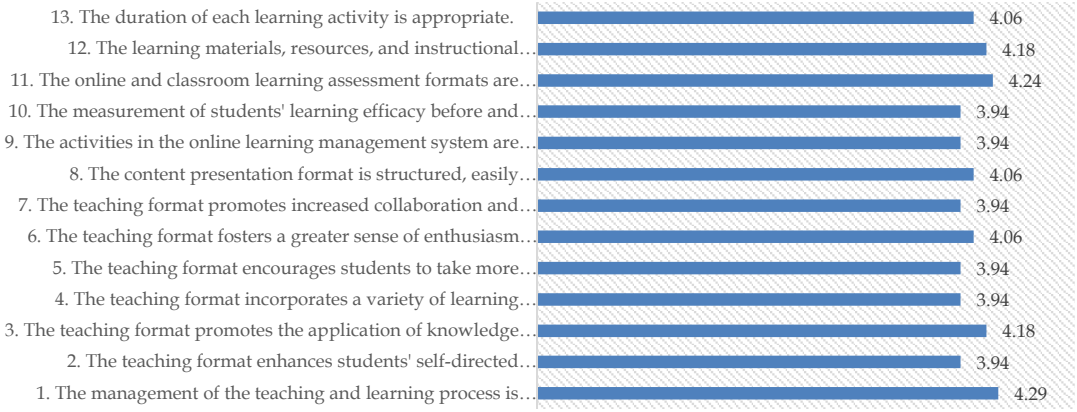

Figure 7: Students' perceptions toward the hybrid teaching format using PBL.

5. Discussion

The findings of the study generally indicated that the students possess a high level of self-directed learning capabilities. The aspect with the highest average score was setting learning goals, which aligns with the fundamental principles of humanistic psychology theory, emphasizing autonomy, self-concept, and the ability to explore alternatives and possess unlimited self-development potential

while taking responsibility for oneself and others (Elias & Merriam, 1980). Regarding the factors influencing self-directed learning capabilities, the study revealed that nurturing, problem-solving experiences, and the use of IT were the three variables that significantly explained self-directed learning abilities, which accounted for over 34% with a statistical significance level of 0.01. Among these explanatory variable predictors, the ability to use IT, followed by nurturing and problem-solving experiences, have the highest to the least predictive power for students' self-directed learning abilities, respectively.

These findings indicate that students who possess high proficiency in utilizing information technology are more likely to exhibit higher self-directed learning capabilities. Recognizing the benefits of technology for learning and perceiving the compatibility between technology use and learning expectations play crucial roles in determining the effective utilization of technology, which, in turn, influences students' learning outcomes (Lai, 2013). Successful learning outcomes are derived from the ability to employ tools for exploration and knowledge acquisition, which are integral components of self-directed learning.

Information technology facilitates rapid and efficient access to knowledge, enabling learners to fully utilize their abilities for learning and make informed decisions regarding suitable learning pathways. This autonomy in choosing learning sources enhances the efficiency of learning, allowing learners to acquire knowledge anytime and anywhere, think critically, solve problems independently, develop confidence, and continually enhance their self-directed learning capabilities. These findings are consistent with the research conducted by Lai (2013), which demonstrated that students' motivation for learning increases when they realize the value and benefits of computer technology and comprehend the alignment between technology and their learning expectations, leading to higher levels of self-directed learning behavior. Similarly, Geng et al. (2019) found that technological readiness positively influences motivation for learning, which, in turn, guides learners in utilizing online learning strategies and achieving learning goals more effectively.

The data analysis results, depicted in Figure 5 and Table 5, indicate that students instructed using the hybrid teaching format exhibited significantly higher levels of self-directed learning abilities compared to those instructed through conventional methods across all dimensions. The dimension with the highest average score is analysis and determination of personal learning needs compared to having the lowest average score in Phase 1. Thus, it is evident that a hybrid teaching design using the problem-based approach is a teaching format that fosters self-directed learning. This approach emphasizes activities that develop learners' ability to plan and evaluate their learning progress, starting from setting learning goals, seeking support, accessing educational resources, and assessing their own learning outcomes. Therefore, it is essential to enable learners to improve their learning because they are motivated to learn, have the opportunity to work at their own level and pace, and can choose content and set learning goals based on their experiences and needs (Donald, 1995). Learners can schedule their learning, which characterizes asynchronous learning (Finol, 2020). Online learning enhances learning efficiency by breaking the confine of a single location.

It promotes understanding among learners (Fitrianaa et al., 2021) and involves PBL, an open-ended problem-solving approach (Phungsuk et al., 2017). PBL activities stimulate motivation and develop learners' self-directed learning skills, encouraging the application of acquired knowledge in problem-solving situations. It fosters learners' critical thinking, reasoning, analysis, and acceptance of others' opinions through collaborative group work. The instructional design process follows PBL guidelines (Hmelo & Lin, 2000; Tan & Marincovich, 2003; Weir, 1974) and self-directed learning steps (Knowles, 1978). Learners' self-directed learning abilities were stronger when compared to traditional teaching methods. These findings align with previous studies conducted by Suksathid (2007), Tepsumetanon and Pasittunyakit (2010), Charoenchim (2012), Phupay (2015), and Sahapiboonchai (2016).

This study investigated the academic performance outcomes of students (within-subject design). The same sample group was taught through traditional teaching methods in first half and hybrid teaching methods using PBL in second half. The results revealed that students exhibited significantly higher post-learning academic performance compared to pre-learning performance, in both conventional and hybrid teaching formats; however, there was a clear distinction in the mean values, indicating that the hybrid teaching approach had a higher percentage increase in average performance compared to the traditional teaching approach. Consequently, it can be concluded that the designed hybrid teaching format proved to be an efficient instructional management approach. This approach motivates students to learn, work at their own proficiency levels, and make progress. Moreover, it enables them to select content and set learning goals based on their experiences and personal aspirations (Donald, 1995). Additionally, it provides opportunities for constant lesson reviews, leading to increased effectiveness in student academic performance (Wulandari et al., 2018). The observed post-learning outcomes were higher than pre-learning outcomes, aligning with previous research findings by various scholars, such as Waithongkam (2015), Khlaisri (2017), Pakaworakun et al. (2017), Wongcharoen (2018), and Bangpoophamorn and Wiriyanon (2019).

The overall feedback of the hybrid teaching using PBL approach was highly positive. This can be attributed to the alignment between the instructional design, learning content, learning objectives, and stimulating learning activities. The collaborative nature of the learning activities by PBL, allowing peers to work together in groups, think critically, and solve problems. That created an enjoyable and challenging learning environment. They engaged in discussions and effectively expressed their thoughts in various activities. Additionally, students demonstrated self-directed learning, as they successfully tackled problem-solving tasks assigned within the hybrid teaching framework. This approach fostered effective problem-solving skills and self-directed learning. The learning format resulted in high levels of student satisfaction, consistent with the research conducted by Waithongkam (2015), Yimyam et al. (2015), Horak and Galluzzo (2017), Wongcharoen (2018), and Bangpoophamorn and Wiriyanon (2019).

6. Conclusions

Amidst the Covid pandemic, traditional classroom learning transitioned primarily to an online format. Nevertheless, this shift faced challenges and did not entirely succeed due to technological constraints and varying internet availability and accessibility in certain regions. As a result, hybrid learning emerged as a more viable and promising alternative. Furthermore, students must also possess the ability on self-directed learning to ensure their academic success for online learning. This study endeavored to address the issue by integrating hybrid learning and problem-solving as a potential solution. The findings revealed that students who engaged in this teaching approach exhibited higher levels of self-directed learning abilities, which were accompanied by improved post-learning academic performance. These results highlight the effectiveness of the instructional design in facilitating collaborative group work, stimulating idea exchange and collective problem-solving, and providing avenues for information search and online learning support. Moreover, the user-friendly and systematic nature of the online learning platform contributed to the overall efficacy of the learning experience. The innovative teaching concept of hybrid teaching using problem-based learning will shed light on the path for future instructional paradigms.

7. Implications

According to the study, the following considerations should be taken into account for an improvement of self-directed learning classroom conduct:

1) Prior to commencing hybrid teaching, instructors need to adequately arrange and set up the classroom environment.
2) Both instructors and students need to be equipped with the abilities and competencies in utilizing technology. This also includes the provision of technology and internet availability and accessibility.
3) It is important to cultivate a positive mind-set on self-directed learning and an acceptance of technology integration in a classroom environment to both instructors and students.

8. Limitation

This research had a limited number of participants on account of the remote location of the campus, and the small number of student admission. Internet coverage and IT facilities were the major problems, found during the experiment. However, the participants attempted to sort out the problems by moving the study sites or spots and sharing some equipment together from time to time.

9. References

Agustiani, I.W.D. (2019) Maximizing teacher roles in shaping self-directed learners, *English Community Journal, 3*(1), 289.

Bangpoophamorn, K., & Wiriyanon, T. (2019). The development of flipped classroom model with self-directed learning to enhance critical thinking in an undergraduate course. *Technical Education Journal*, *10*(2), 41–50.

Barrows, H.S. (2000). *Problem based learning applied to medical education*. Springfield IL: Southern Illinois University Press.

Best, J.W. (1981). *Research in Education*. New Jersey: Prentice – Hall.

Bolhuis, S. (2003). Towards process-oriented teaching for self-directed lifelong learning: A multidimensional perspective. *Learning and Instruction*, *13*(3), 327-347. https://doi.org/10.1016/S0959-4752(02)00008-7

Bolhuis, S., & Voeten, M. J. M. (2001). Toward self-directed learning in secondary schools: What do teachers do?. *Teaching and Teacher Education*, *17*(7), 837–855. https://doi.org/10.1016/S0742-051X(01)00034-8

Borich, G.D. (2000). *Effective Teaching Methods* (4th ed.). New Jersey: Prentice Hall.

Brockett, R. G., & Hiemstra, R. (Ed.) (2018). *Self-Direction in Adult Learning: Perspectives on Theory, Research, and Practice* http://taylorandfrancis.com

Carman, J. M. (2002, October). *Blended learning design: Five key ingredients.* http://blended2010.pbworks.com/f/Carman.pdf

Charoenchim, S. (2012). *Self-directed learning ability of preservice teachers*. Bangkok: Kasetsart University Press.

Donald, M. M. (Ed.) (1995). *Teach writing as a process not product* (5th ed.). Boynton.

Driesen, G. (2016, January 8). *The difference between blended and hybrid learning.* https://www.anewspring.com/blended-and-hybrid-learning

Duch, B. J., Groh, S. E., & Allen, D. E. (2001). *The power of problem-based learning*. Stylus Publishing.

Edens, K. (2000). Preparing problem solvers for the 21st century through problem-based learning. *College Teaching, 48*(2), 55–61.

Elias, J. L., & Merriam, S. (1980). *Philosophical Foundations of Adult Education.* Huntington. New York: Robert E. Krieger Publishing Company.

Equitable Education Research Institute [EEFI]. (2022, May 2). *Learning Loss.* https://research.eef.or.th/learning-loss-recession/

Evensen, D. H., & Hmelo, C. E. (2000). *Problem-based learning: A research perspective on learning interactions.* Lawrence Erlbaum Associates.

Finol, M.O. (2020, March 26). *Asynchronous vs. synchronous learning: A quick overview*. https://www.brynmawr.edu/news/asynchronous-vs-synchronous-learning-quick-overview

Fitrianaa, N., Widayanti, F. D., & Firmanto, B. (2021). Problem-based learning virtually in blended learning model for chemistry lessons during the COVID-19 pandemic. *Journal Pendidikan Sain*, *9*(1), 14–25.

Funchian, N. (2021, June 22). *Hybrid Learning, the Solution to Modern Education*. https://www.trueplookpanya.com/education/content/89235

Garnham, C., & Kaleta, R .(2002). *Introduction to Hybrid Courses.* https://hccelearning.files.wordpress.com/2010/09/introduction-to-hybrid-course1.pdf

Geng, S., Law, K. M. Y., & Niu, B. (2019). Investigating self-directed learning and technology readiness in blending learning environment. *International Journal of Educational Technology in Higher Education, 16*(17), 1-22. https://doi.org/10.1186/s41239-019-0147-0

Haryani, S., Masfufah, Wijayati, N., & Kurniawan, C. (2018). Improvement of metacognitive skills and students' reasoning ability through problem-based learning. *Journal of Physics: Conference Series*, *983*(1), 1-5. https://doi.org/10.1088/1742-6596/983/1/012174

Hmelo, C. E., & Lin, X. (2000). *Becoming self-directed learners: Strategy development in problem-based learning.* Lawrence Erlbaum Associates.

Horak, A. K., & Galluzzo, G. R. (2017). Gifted Middle School Students' Achievement and Perceptions of Science Classroom Quality During Problem-Based Learning. *Journal of Advanced Academics*, *28*(1), 28–50. https://doi.org/10.1177/1932202X16683424

Hurlock, E.B. (1984). *Child Development*. New York: McGraw Hill Book Company.Imchit, P. (2013). A comparative study of ethical and analytical thinking of grade 3

students between learning through socioscientific-based instruction and problem-based instruction. *Journal of Education, 7*(3), 50–58.

Kuawnamchum, C., Anusasananan S., & Wong-Ngam, P. (2017).Theoretical Models and Researches Involving Causal Factors of Self - directed Learning. *Journal of HR Intelligence*, *12*(1), 125-140.

Khlaisri, P. (2017). *Development of the instructional model using blended learning and metacognition for faculty of education students in Rajabhat University in the Northeastern* (Doctoral dissertation). Curriculum and Instruction, Dhurakij Pundit University, Thailand.

Knowles, M.S. (Ed.). (1978). *The adult learner: A neglected species* (2nd ed.). Gulf Publishing.

Knowles, M.S. (1975). *Self-directed learning: A guide for learner and teacher*. Association Press.

Lai, C. (2013). A framework for developing self-directed technology use for language learning. *Language Learning & Technology, 17*(2), 100–122.

Lai, C. & Mingyue, G. (2011). Self-regulated out-of-class language learningwith technology. *Computer Assisted Language Learning*, *24*(4), 317-335. http://dx.doi.org/10.1080/09588221.2011.568417

MicroTek. (2017, February). *What is hybrid learning? How do hybrid and blended learning differ?*. https://blog.mclabs.com/t-tof-what-is-hybrid-Learning

Mingsiritham, K. (2009). Self-directed learning on web-based learning. *Journal of Education, 32*(1), 6–13.

Office of the Education Council [OEC]. (2007). *Problem-based learning*. Sor Kor Sor, Thailand.

Ossiannilsson, E. (2017, April 15). *Let the learners take the lead for their lifelong learning journey*. https://www.igi-global.com/chapter/let-the-learners-take-the-lead-for-their-lifelong-learning-journey/163492

Pakaworakun, C., Hoksuwan, S., & Chompulong, N. (2017). A development of instructional system with hybrid learning for undergraduate students at Rajabhat University. *Journal of Educational Measurement, 23*(16), 66–77.

Phungsuk, R., Viriyavejakul, C., & Ratanaolarn, T. (2017). Development of a problem-based learning model via a virtual learning environment. *Kasetsart Journal of Social Sciences*, *38*(1), 297–306.

Phodong, A., & Jarujit, N. (2022). The Model Development Competency Learning Designers to Teacher by Integrating Active Learning. *Journal of Social Science and Buddhistic Anthropology*, *7*(8), 373-388.

Phupay, S. (2015). *Development of the learning process based on the self-directed learning concept for promotion of responsibility of pre-service teachers* (Doctoral dissertation). Curriculum and Instruction, Rajabhat Mahasarakham University, Thailand.

Piroj, K. (2017, December 10). *Taro Yamane's formula: Defining Sample Size.* https://greedisgoods.com/taro-yamane/

PPTV. (2022, August 27). *"Lifelong Learning" Educational Evolution amidst Social Transformation*. https://www.pptvhd36.com/news/สังคม/179244

Ruangsri, B., Wisetkan, A., Noonsakun, S., & Rungrangsee, W. (2021). teaching and learning in the New Normal Covid-19 era using the format On-site teaching and learning. *Journal of Human Society, the faculty of Humanities and social sciences, Nakhon si Thammarat Rajabhat University*, *11*(2), 29-45.

Sahapiboonchai, S. (2016). *The influence of emotional quotient and adversity quotient toward self-directed learning characteristics of non-formal and informal education students in Bangkok Metropolitan* (Master's thesis). Chulalongkorn University, Thailand.

Scheiderer, J. (2021, February 10). *What's the difference between asynchronous and synchronous learning*?. https://online.osu.edu/resources/learn/whats-difference-between-asynchronous-and-synchronous-learning

Starfish Academy. (2022, August 15). *Self-directed Learning, Fostering Self Learning Abilities* [Blog post]. https://www.starfishlabz.com/blog/928-self-directed-learning.

Suksathid, W. (2007). *Self-directed learning for adult learners by web-based learning* (Doctoral Dissertation). Adult Education, Srinakharinwirot University, Thailand.

Susanti, N., Juandi, D., & Tamur, M. (2020). The effect of problem-based learning (PBL) model on mathematical communication skills of junior high school students - A meta-analysis study. *Jurnal Teori dan Aplikasi Matematika*, *4*(2), 145–154.

Tan, O. S., & Marincovich, M. (2003). *Problem-based learning innovation: using problems to power learning in the 21st century*. Thomson.

Teo, T., Tan, S. C., Lee, C. B., Chai, C., Koh, J., Li, C., & Cheah, H. (2010). The self-/directed learning with technology scale (SDLTS) for young students: An initial development and validation. *Computers & Education*, *55*(4), 1764-1771. https://doi.org/10.1016/j.compedu.2010.08.001

Tepsumetanon, P., & Pasittunyakit, S. (2010). *Self-directed learning of the Department of Educational Foundation students*. Ramkhamhaeng University, Thailand.

Thienthong, T. (2021, May 17). *Five instructional approaches tailored for diverse regions across the country by the Ministry of Education*. zttps://www.prd.go.th/th/content/category/detail/id/9/iid/19133

Tsoi, M. F., & Goh, N. K. (2008). Addressing cognitive processes in e-learning: TSOI hybrid learning model. *US-China Education Review*, *5*(8), 29–35.

Tungchityuengyong, D. (2022, March 18). *New classroom design with hybrid learning* [Blog post]. https://avl.co.th/blogs/hybrid-learning

Väljataga, T., & Fiedler, S. (2009). Supporting students to self-directed intentional learning projects with social media. *Educational Technology & Society*, *12*(3), 58-69.

Waithongkam, Y. (2015). *Development of the blended instructional model with a web-based self-directed learning approach* (Doctoral dissertation). Education Technology, Ramkhamhaeng University, Thailand.

Weir, J. J. (1974). Problem solving is everybody's problem. *The Science Teacher*, *41*(4), 16–18. http://www.jstor.org/stable/24123495

Wisetdonwai, J. (2022). *Self-Directed Learning in Post-Covid Pandemic: Instructional Settings of Global Exploration*. https://www.educathai.com/knowledge/articles/535

Wongcharoen, W. (2018). *Learning provision using problem-based learning with augmented reality technology to develop analytical and problem-solving thinking skills for Mathayom Suksa IV students* (Master's thesis). Curriculum and Instruction, Dhurakij Pundit University, Thailand.

Wulandari, N. I., Wijayanti, A., & Budhi, W. (2018). Effectivity of learning model problem-based learning toward science learning outcomes observed from students' communication skills. *Journal Pijar MIPA, 13*(1), 51–55.

Yamane, T. (1973). *Statistics: An Introductory Analysis* (3rd ed). New York: Harper and Row.

Yaso, M. (2013, July 20). *21st century learning*. http://www.gotoknow.org/posts/542974

Yimyam, S., Charuwatcharapaniskul, M., Chareonsan, J., Na Ayutthaya, A. I., Xuto, P., & Chaloumsu, N. (2015). Developing blended learning for the 21st century learning skills. *Nursing Journal, 42* (Supplement), 129–140.