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เทคนิคการสอนเพื่อการออกแบบกิจกรรมการเรียนรู้ฟิสิกส์ภายใต้สถานการณ์การแพร่ระบาดของเชื้อ COVID-19 : การวิเคราะห์แผนการจัดการเรียนรู้ของนิสิตครูก่อนประจำการ

Teaching Techniques for Designing Physics Learning Activities during the COVID-19 Pandemic: Analysis of Pre-service Teachers' Lesson Plans

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บทคัดย่อ

งานวิจัยนี้มีจุดมุ่งหมายเพื่อ 1) วิเคราะห์บทความวิจัยทางด้านการเรียนการสอนฟิสิกส์ที่ตีพิมพ์ในช่วงวิกฤตการณ์ COVID-19 และตรวจสอบเทคนิคการสอนที่ใช้ส่งเสริมความเข้าใจมโนทัศน์ฟิสิกส์ ทักษะกระบวนการทางวิทยาศาสตร์ และสมรรถนะสำคัญห้าประการ ของนักเรียนระดับชั้นมัธยมศึกษาตอนปลาย 2) วิเคราะห์วิธีการใช้เทคนิคการสอนออนไลน์ที่นิสิตครูฟิสิกส์ก่อนประจำการเลือกใช้และปรากฏในแผนการจัดการเรียนรู้ภายใต้บริบทการสอนแบบออนไลน์ การศึกษานี้ใช้วิธีการวิเคราะห์เนื้อหาและการลงรหัสแบบอุปนัยของเอกสารบทความวิจัย 79 ฉบับ และแผนการจัดการเรียนรู้ 85 ฉบับ ผลการวิจัย พบว่า ภายใต้สถานการณ์ COVID-19 การใช้โปรแกรมประยุกต์ผ่านโทรศัพท์เคลื่อนที่ การใช้โปรแกรมจำลองสถานการณ์ และวีดิทัศน์แบบออนไลน์ เป็นวิธีการที่ถูกใช้มากที่สุดสำหรับพัฒนานักเรียนในแต่ละด้าน นิสิตครูฟิสิกส์ก่อนประจำการมีการบูรณาการเทคนิคการใช้สื่อดิจิทัลในแผนการจัดการเรียนรู้ฟิสิกส์ได้หลากหลายวิธี เช่น การอธิบายมโนทัศน์ การฝึกทักษะกระบวนการทางวิทยาศาสตร์ และการเรียนรู้ทักษะชีวิตผ่านการจัดกิจกรรมกลุ่มร่วมกันแบบออนไลน์ นอกจากนี้ยังพบว่า วีดิทัศน์แบบออนไลน์เป็นเทคนิคที่ครูก่อนประจำการเลือกใช้มากที่สุดในการสร้างความเข้าใจมโนทัศน์ทางฟิสิกส์ให้กับนักเรียน การใช้โปรแกรมจำลองสถานการณ์ถูกเลือกใช้มากที่สุดในการพัฒนาทักษะกระบวนการทางวิทยาศาสตร์ให้กับนักเรียน รวมถึงการใช้วีดิทัศน์แบบออนไลน์ประกอบการใช้คำถามกระตุ้นการคิดถูกเลือกใช้มากที่สุดสำหรับส่งเสริมสมรรถนะห้าประการ

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Abstract

This research had two aims: first, to analyze research articles on physics instruction during the COVID-19 crisis and determine teaching techniques that enhanced upper secondary students' physics concept understanding, science process skills and five key competencies; second, to analyze the teaching techniques selected by pre-service physics teachers and how they applied them in lesson plans in an online context. A content analysis and an inductive coding were conducted on 79 selected research articles and 85 lesson plans in this study. The results showed that smartphone application, simulation and online clip video were the most frequently used to develop students during the COVID-19 pandemic. In addition, the findings showed that pre-service physics teachers integrated techniques of using digital instructional materials in their physics lesson plans based on various methods, such as explaining concepts, practicing science process skills and learning life skills through online group activities. Besides, the findings showed that the most frequently used teaching techniques were online video clips aimed at building students' understanding of physics concepts, simulations for developing students' science process skills, and online video clips with a set of questions for promoting students' five key competencies.

Keywords: physics teaching technique, physics concepts, science process skills, five key competencies, pre-service teacher

Introduction

Since 2019, the COVID-19 pandemic has significantly impacted teaching design in Thailand because of school closures and population lockdowns. Teaching at all school levels has been adjusted to remote learning or blended learning because of the need for social distancing (Oxford Policy Management and United Nations, 2020). Moreover, the online teaching environment has been designed to support the efficiency and effectiveness of students' learning as much as possible such as lectures in online classrooms, virtual class activities, and freely available software have been implemented in every subject area, including physics, which is essential for students to apply, develop and create innovative technology, such as nanotechnology, electronics, physics and forensics, in their future work (Renata, 2013). Therefore, physics content is included as a core subject area in curricula at all levels of education.

Physics is a core subject in the Thai science curriculum, which emphasizes mechanics, waves, electricity and magnetism, modern physics, nuclear physics and particle physics (Ministry of Education Thailand, 2008, 2019). Both in-service and pre-service physics teachers need to plan their teaching designs according to the physics learning indicators defined in this curriculum. It focuses on using the inquiry method to develop scientific concepts and processes. For instance, tenth-grade students are taught to experiment and explain relations among displacement, time, velocity, and acceleration of motion in a straight line from graphs and equations (i.e., the third physics learning indicator) through a traditional hands-on physics laboratory design. However, this teaching method could not be applied in the classroom because of the COVID-19 pandemic. Many previous studies have shown that hands-on physics learning activities have

shifted from traditional teaching in the new normal era. Campari et al. (2021) suggested that using slow-motion videos on a mobile phone or in a video-based laboratory for conducting physics experiments at home would be one way of designing interactive online activities. Moreover, Hamed and Aljanazrah (2020) introduced a virtual laboratory operated through the Internet using computers or smartphones in physics classes and as a substitute for a physical laboratory. These results may reflect how physics teachers have created new learning activities by effectively applying new teaching techniques in both online and traditional online classrooms.

In addition, physics teachers need to consider the five key competencies—communication thinking capacity, problem-solving capacity, capacity for applying life skills, and capacity for technology application—when they design learning activities (Ministry of Education Thailand, 2008, 2019). In new normal situations, many ways of helping students develop their competencies have been adopted from previous research. For example, simulation, or video animation combined with interactive questions on smartphones can assist students in understanding and analyzing abstract concepts as well as training their thought processes to reach reasonable conclusions. Furthermore, Soparat et al. (2015) found that learners' five key competencies and learning outcomes were enhanced by problem-based learning activities; for instance, students used various ICT media to collect, analyze and share data in their tasks or missions. In addition, group work or teams can help students develop inquiry skills, thinking skills, and social harmony by strengthening positive interpersonal relationships and effective decision-making skills. Pratoomrat (2021) recommended several ways to promote students' key competencies during the COVID-19 crisis, such as applying STEM education, active learning activities and problem-based learning in the classroom. These activities have helped Thai students become skilled learners and potential innovators. Based on the findings of previous studies, it may be inferred that Thai teachers should focus on interesting topics related to problems in daily life and integrated with ICT tools and online groupwork to design active and creative activities. Lessons plans based on such teaching designs will enable Thai students to improve their competencies during crises.

Pre-service physics teachers have practiced teaching in schools for one year before they advance to in-service teachers, according to the requirements of the Teachers' Council of Thailand (2013). However, during the COVID-19 pandemic, pre-service teacher institutes were challenged to find new strategies or best practices to train student teachers in developing new skills suitable for online learning before their practicum in the fourth year of the program. However, only a few previous studies have focused on physics teaching techniques that are appropriate during pandemic crises. Thus, in this study, the researcher gathered articles that focused on effective physics teaching techniques and their evaluation. Only articles that had been previously reviewed and their research quality confirmed were selected for inclusion in this study. The selected articles were analyzed for techniques used to teach physics to students in the 10^{th} to 12^{th} grades during the COVID-19 pandemic, including the following: 1) Physics Concepts Understanding (PCU) ; 2) Science Process Skills (SPS) ; and 3) Five Key Competencies (FKC). These techniques were then presented

to pre-service physics teachers, who were requested to use them in designing their lesson plans and applying them in real teaching situations.

The findings of this study revealed essential teaching competencies that physics pre-service teachers need to be trained in at teacher development institutes. They can be implemented by university lecturers or undergraduate curriculum developers in designing practicum courses, physics teaching methodology courses and physics instructional media courses. They can help physics pre-service teachers develop their competencies and apply new techniques to physics teaching during the COVID-19 pandemic and in other situations in Thai society, particularly those that impact student learning in the future.

Research Objectives

This research objectives were defined as follows:

1) To analyze research articles related to physics instruction during the pandemic to find teaching techniques that promoted tenth-to-twelfth grade students' PCU, SPS, and FKC.

2) To analyze the teaching techniques which physics pre-service teachers selected and applied in their lesson plans after they were suggested the most effective teaching techniques analyzed from research articles.

Methodology

In this study, the research procedure was divided into two phases. They were described in detail as follows:

Phase 1: Analysis of the Research Articles

The samples were the academic research articles which were selected according to the following criteria: 1) published in open-access international conference proceedings in physics education indexed by SCOPUS; 2) published during the COVID-19 pandemic period from 2019 to 2021; 3) focused on physics teaching at the upper secondary level in the Southeast Asian context. Based on these criteria, 79 articles were selected for inclusion in this study. Content analysis and inductive coding were used in this study. Keywords related to physics teaching techniques in the sample were categorized and coded, and their frequency was counted and ranked (Bowen, 2009; Lincharearn, 2012; Saldaña, 2021). These findings were presented to the pre-service physics teachers for their use in designing lesson plans, which were analyzed in phase 2.

Phase 2: Analysis of Pre-service Physics Teachers' Lesson Plan

Samples of the pre-service physics teachers' lesson plans were selected according to the following criteria: 1) created by three pre-service physics teachers who were supervised by a researcher and were not named in this research; 2) used in online teaching in the second semester of the academic year 2021; and 3) used only at the upper secondary school level. Based on these criteria, 85 lesson plans were included in the sample. Content analysis and inductive coding were used in this study. The keywords showing the

applied teaching techniques in each plan were grouped and coded, and their frequency was counted (Bowen, 2009; Lincharearn, 2012; Saldaña, 2021).

Results

Phase 1: Analysis of the Research Articles

Table 1 shows the top three keywords in the 79 research articles related to students' learning development during the COVID-19 pandemic. They were divided into three categories: 24, 19 and 36 articles related to effective teaching techniques used to develop PCU, SPS and FKC, respectively. It was found that smartphone, simulation, and video clips were the most applied in online classrooms for enhancing students' PCU, SPS, and FKC.

Table 1

Analysis of research articles (n = 79)

Top three ranking	Frequency of effective physics teaching techniques in recent research articles in physics education		
	PCU (n = 24)	SPS (n = 19)	FKC (n = 36)
1	- Use *smartphone application* to design activity (5) - Use *simulation* to construct and explain concepts (5)	- Use *simulation* in the experiment or construct graphical representation (8)	- Use *online clip video* to develop thinking skill or problem solving skills or digital skills (7)
2	- Use animation video to construct physics concept (3) - Use online clip video to design activity (3) - Create new electronics material for teaching (3)	- Use online clip video to practice communicative scientific presentation skill or construct math representation (4)	- Create electronics material for develop thinking skill or problem solving or digital skill (6)
3	- Use *comic script* to explain concepts (2)	- Use *Tracker* to collect data (2) - Use *Augmented reality (AR)* to help student visualize abstract data (2)	- Use *simulation* to develop critical thinking (5) - Use *smartphone application* to develop critical thinking or problem solving skills (5)

Phase 2: Analysis of Pre-service Physics Teachers' Lesson Plans

Table 2 shows the teaching techniques used at the highest frequency by three pre-service physics teachers (Code names: A, B and C) in online classrooms during the COVID-19 pandemic. Each pre-service physics teacher created 30, 26 and 29 lesson plans for online teaching, respectively.

Table 2

Effective physics teaching techniques for enhancing students' PCU, SPS, and FKC used in lesson plans

Pre-service teacher code name	The highest frequency of teaching techniques appear in lesson plans (n = 85)	How to use teaching techniques
PCU analysis		
A	Online clip video (8)	- show the situations in daily life related to concepts of 2D motion, momentum, and collisions. - ask a set of question to develop physics concepts.
B	Online clip video (6)	- explain electricity concepts, direct circuits, and electrical energy. - ask a set of question.
C	Smartphone application (8)	- assign student do an EXIT Ticket - test students' understanding. - play an online quiz game for lesson review.
SPS analysis		
A	Simulation (7)	- demonstrate a laboratory procedure with online channels. - assign students to collect, record data, and create a graph on their worksheet (individual work).
B	Online clip video (7)	- demonstrate a laboratory procedure with online channels.
C	Simulation (4)	- demonstrate a laboratory procedure with online channels by video or real time show.
FKC analysis		
A	Online clip video (13)	- stimulate thinking process with situation in videos. - ask students with a set of questions
B	Online clip video (6)	- stimulate thinking process with situation in videos. - ask students with a set of questions
C	Online Group work (10)	- stimulate thinking process with topic discussion. - practice an oral presentation. - do a lab work in group. - play a team game for lesson review. - solve a physics problem in group.

Figures 1-3 show the total frequency of techniques used in pre-service teachers' lesson plans for enhancing students' PCU, SPS, and FKC, respectively. The results indicate that online video clips and simulation were used widely for designing physics lesson plans.

Figure 1

The total frequency of techniques used for enhancing students' PCU

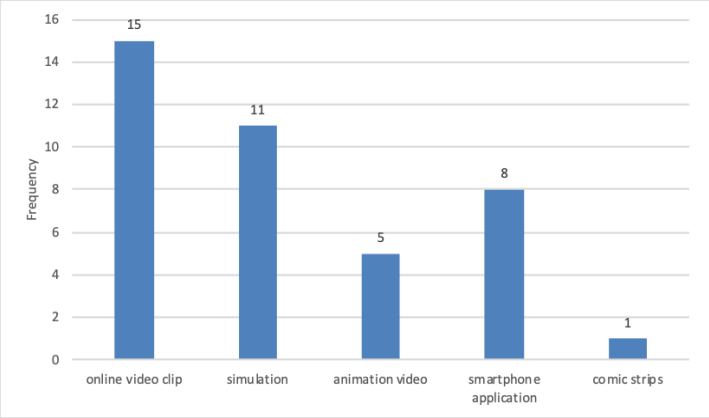


Figure 2

The total frequency of techniques used for develop students' SPS

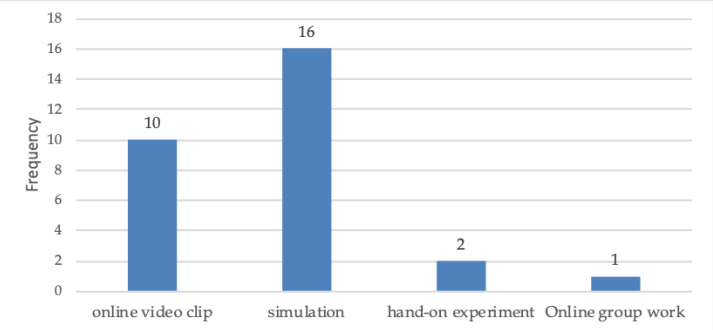
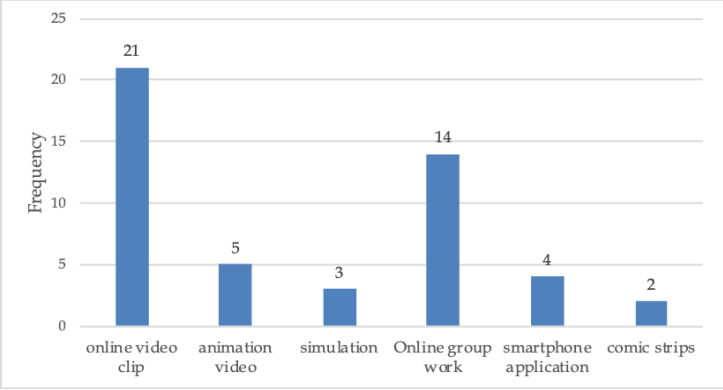


Figure 3

The total frequency of techniques used for develop students' FKC



Discussion

As shown in Table 1, the analysis revealed four interesting findings. First, digital teaching material was selected to construct lesson plans to promote upper secondary science students' PCU, SPS, and FKC in the Southeast Asian context, especially for applications using smartphones and online resources. The findings indicated that digital technologies were widely used, applied and integrated in online classroom and learning activity design during the COVID-19 crisis (Ana et al., 2020). Second, PCU construction techniques were used in online classrooms, as revealed in previous research on physics education. The results showed that smartphone applications and simulations were the most frequently used to assist students in learning effectively, such as by sharing and accessing materials online, as well as communicating during mandatory social distancing (Noah, 2019). Third, simulations were the most frequently applied in online classrooms to develop students' SPS. Used instead of science kits, simulations helped students study abstract physical phenomena when they were not able to directly observe experiments. Students could redo the experiment and change the physical quantity scale of events in an online laboratory to observe and collect data (Celik, 2022). Lastly, online video clips were the most frequently used to develop students' FKC. The video clips were easily accessed online, such as updated news on YouTube. In addition, the clips presented segments of data and addressed discussion topics that did not have clear conclusions, which motivated students to find the answers, come to reliable conclusions, or solve problems through observing, thinking, analyzing data, recalling prior knowledge, or interpreting evidence shown in the video clips (Hikmawati et al., 2021).

In brief, the most common teaching techniques used to enhance students' PCU, SPS, and FKC were educational digital technology materials. Other techniques, such as animation videos, comic strips, and online group work, were less frequently used. The techniques used in these findings were recommended to three pre-service physics teachers who designed online physics lesson plans before they started internships in secondary schools from November 2021 to February 2022. In phase 2 of the study, the findings revealed that these teachers used the recommended techniques in several ways.

As shown in Table 2 and Figure 1, the pre-service physics teachers most frequently selected online video clips to construct physics concepts for their students, followed by simulation, smartphone applications, animation videos, and comic strips in that order. There are three points to discuss regarding this finding. First, online video clips and animation videos were not used to directly transfer lectures or physics content directly, but they were used to introduce challenging situations to students, in addition to a set of questions, to build new concepts. Challenging situations and questions presented in the video clips helped students understand physics concepts in depth. This finding was consistent with study of Richtberg and Girwidz (2019). They found that interactive online videos with integrated tasks helped students learn actively. Second, in the present study, the findings showed that the pre-service physics teachers demonstrated physics equations and laws using physics simulations. The teachers selected simulations because the students could select physics variables and construct physics graphs to show relationships clearly. Similar to study of Mariam (2015), in this study, the students were facilitated in proving equations

or physics law based on collected data and graph analyzes. She indicated that simulations assisted students in working with graphs and finding relevant information, which led to their improved understanding of physics concepts. Third, smartphone applications were used for playing games or presenting quizzes to check students' understanding of concepts. Private smartphones were used for individual testing. The lesson plans included applications such as Kahoot, Google Form and Blooket. These programs not only helped the teachers create quizzes but also provided prompt feedback to the students. The use of smartphone applications in online classrooms helped the students concentrate on their studies and enhanced their understanding of the main physics concepts. Henukh and Guntara (2020) found that smartphone applications, such as Kahoot, motivated students to learn and understand physics concepts.

As shown in Table 2 and Figure 2, the three pre-service physics teachers who participated in this study used simulations the most frequently to improve students' SPS, followed by online video clips, real-time hands-on experiments shown in online channels, such as Google Meet or Zoom, and online group work in that order. The results of the analysis showed that these teaching techniques were used to design possible online experiments and to develop students' basic and integrated SPS. Regarding the former, all techniques were used to develop these skills, especially observation skills using only eyes and ears in the online context, classifying data and communicating skills by creating graphs and having discussions through online channels. Regarding the latter, skills such as controlling variables, formulating hypotheses and interpreting data were improved in the online context. The pre-service physics teachers selected these techniques to design their lesson plans because simulations or video clips can be used to animate or visualize dynamic changes in scientific processes that are difficult to observe (Ryoo & Linn, 2012). Moreover, some skills, such as manual skills, cannot be practiced through online channels, particularly those related to handling laboratory instruments. They displayed only outcomes that were pre-programmed and could only be manipulated to a limited extent. Although simulations or video clips were applied in the online context, they cannot be used to develop all SPS (Karlsson et al., 2013).

As shown in Table 2 and Figure 3, online video clips were the most frequently selected to enhance the students' FKC, followed by online group work, animation videos, smartphone applications, simulations and comic strips in that order. The data analysis revealed three issues concerning the FKC (i.e., communication capacity, thinking capacity, problem-solving capacity, capacity for applying life skills and capacity for technology application). First, students' thinking capacity was addressed using online video clips, animations, simulations, comic strips and group discussions in the online classrooms. Based on the pre-service teachers' lesson plans, these techniques were applied in the introductions, which helped the students assimilate data in pictures, texts or audio recordings of situations shown in video clips. The students thought about and found solutions based on their prior knowledge. The teachers provided questions or discussion topics to stimulate the students' thinking processes and to engage them in the main learning activity. These findings were consistent with previous studies and showed that these techniques could improve students' thinking skills (Adri et al., 2020). Second, the students' communication capacity was developed by the online group tasks. This technique assisted students in sharing ideas in groups and in

practicing oral presentations through online channels. Furthermore, clear instructions before each task effectively supported students' communication, as shown by Soon and Sarrafzadeh (2010). Third, the students' problem-solving capacity and capacity for applying life skills, such as teamwork, were improved by using online group work. Physics problems were assigned to each group, and the group members worked together to solve problems. When the students faced a problem during a task, the teachers could provide suggestions or hints that motivated them to solve problems gradually. Moreover, the group process assisted the students in completing tasks and learning together by correcting errors (Mayende et al., 2015). Lastly, using smartphone applications with digital devices increased students' capacity to use technology applications. The results of the lesson plan analysis showed that the students used their phones not only for anonymous commenting activities but also for game activities to assess their learning. However, smartphones were less frequently used to develop this competency because of the unstable signal connection instability in the classroom. This may be one reason that the pre-service teacher rarely selected this technique. In summary, the five key competencies were enhanced by the use of various teaching techniques, especially the integration of digital tools in online learning activities. Online group activities were also used to promote the students' competencies.

The results of this study showed that digital instructional materials were variously applied in online classrooms to enhance students' understanding of physics concepts, science process skills and the five key competencies. The findings also showed the following:

1) More techniques were used to enhance the five key competencies compared with scientific concepts and science process skills. This finding may imply that the students tended to be promoted their competencies.

2) Regarding PCU, the teachers selected simulations to construct abstract concepts and prove relevant equations and relations between physics quantities because of their multiple functions and clear presentation of virtual phenomena.

3) Regarding SPS, digital tools did not improve skills related to the use of laboratory instruments, such as experimental skills and measurement skills.

4) Regarding FKC, online group work promoted multiple competencies, such as communication skills, life skills and thinking skills, depending on the design of the learning activities.

5) Some techniques found in reviewing the research articles selected for this study were not included in the pre-service teachers' lesson plans, such as AR, e-books, or STEM activities. It was possible that the pre-service teachers had not practiced using these techniques. Therefore, pre-service teacher institutes should design new courses to develop these skills, which would provide pre-service teachers with more options for designing lesson plans effectively and suitably during crises, such as the COVID-19 pandemic.

Recommendations

Recommendations for application

The findings may be applied to design new syllabuses or courses for promoting the essential teaching skills or teaching techniques, especially digital skills, which physics pre-service teachers need for their practicum in the fourth year of program or in their work as in-service teachers. Besides, the supervisors may advise own pre-service teachers on selecting digital materials or activities to be appropriate for the content being taught and the characteristics of the learners in their online classrooms.

Recommendations for the future research

A limitation of this study is that it did not address the issue of promoting attitudes towards science and the scientific mind. Another limitation is that this study did not consider pre-service teachers' use of the same teaching techniques in their work as in-service teachers. The findings of future studies could show teachers' development in choosing techniques that are appropriate in changing and uncertain situations. Future research is recommended to explore these interesting issues.

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