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The Physics Classroom in an Online 3D Virtual World: A Thai High School Teacher Needs Analysis

Choojit Sarapak, Surat Sukman*, Prayut Kong-In, Khunapat Sonsrin, Oranuch Nakchat, Jutapol Jumpatam, and Jutamas Yoomark

Abstract—**The study set out to examine the actual and desired needs of Thai high school physics teachers in the 2021 academic year from a sample of 44 teachers in Thailand's northeastern Surin Province. Also, assessment was undertaken concerning each teacher's 'order of needs' from the 41 items presented for evaluation to the teachers. Moreover, there were three main categories in the study's assessments. These were the teachers' opinions on the use of 3-dimension virtual learning (3DVL) teaching media in physics for, 1) a mechanics laboratory, 2) an electromagnetism laboratory, 3) and a wave, sound, and light laboratory. The questionnaire was examined by five experts with a confidence value of 0.97. The data were analyzed using descriptive statistics including the mean and standard deviation. Moreover, a modified version of the priority needs index (PNIModified) was used to assess the 'order of needs' of each teacher in teaching a 3DVL. The results of the study revealed that physics teachers believed that the overall readiness in teaching and learning management of the three groups of physics laboratories were at a moderate level. The teachers also felt that the need for computer-assisted teaching materials and 3DVL science and physics laboratories for high school students was at a high level in all three categories. Concerning each teacher's 'order of needs,' it was determined that the top five teaching needs were for the spectral studies of hot gases (1), followed by teaching parallax (2), the need to teach light interference patterns (3), the polarization of light (4) and then light diffraction and diffraction grating (5).**

Index Terms—**Augmented reality, immersive environments, priority needs index, Thailand, virtual reality.**

I. INTRODUCTION

Science plays a critical role in the development of a country because science brings new technological products to help improve a nation's citizen's quality of life. Moreover, innovative technologies provide opportunities for improving, enhancing, and development of education and learning processes [1]. Therefore, technology, digital media, and software tools can be effective in the learning process, while additionally changing the way students and teachers interact [2].

Science education is different from other subjects in that it is an empirical field requiring experimentation in science laboratories whose modern equipment motivates students' learning process. However, over the past two years, traditional science education through science lab experimentations has become practically impossible due to the close of traditional classrooms due to the COVID-19 pandemic [3].

Fortunately, remote and virtual labs have sprung up around the world, with varying degrees of remote user manipulation and control during the pandemic [1], [4], [5]. This is confirmed by an analysis of 68 augmented reality (AR) implementations in educational environments from which the research team concluded that increased learning performance and motivation were the most commonly mentioned results [6].

In another study, a mobile-enabled AR application was used to enhance the traditional manuals with virtual content including videos and simulations which resulted in higher final exam scores than students who used paper-based manuals for laboratory experiments [7].

In another study from Saudi Arabia, science 3DVLs was stated as an effective means for student lab experiments for several reasons [8]. These were using computer software for lab activities are less expensive and more efficient. Also, as 3DVL experiments can be repeated multiple times, risks are reduced once an actual hands-on experiment is attempted. Finally, 3DVLs help learners explore anomalous data.

Virtual laboratories can also be useful in preparing learners before they touch a real lab experiment [9]. In virtual chemical labs, digital tools can be used to reduce costs and any potential hazards [10]. However, as Chan *et al.* [10] have suggested in their literature review, moving the traditional labs to an online world is challenging and requires online digital tools, such as videoconferencing applications, e-learning platforms, and online videos.

In another Greek literature review of AR in higher education STEM learning, the authors concluded that there is a lack of studies in STEM (especially Math and Technology) and a scarcity of location-based and marker-less AR applications [11]. Similarly, a literature review on VR use in undergraduate engineering and science courses found that most studies were focused on science and involved a single 2D experience using software purchased from a software vendor. Moreover, most studies perceived that virtual labs were a teaching approach in which instruction was done without any human-to-human interaction. Positive outcomes were mainly attributed to design novelty and improved student motivation [12].

In yet another Greek AR and VR study using 14 K-12 volunteer teachers, the authors reported that 75% of the teachers felt that video lectures adequately explained and demonstrated each module's concepts [13]. Digital storytelling was also found to be an effective tool combined with AR and VR techniques.

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Choojit Sarapak, Surat Sukman, Prayut Kong-In, Khunapat Sonsrin, Oranuch Nakchat, Jutapol Jumpatam, and Jutamas Yoomark are with Surindra Rajabhat University, Thailand.

*Correspondence: suratsukman.srru@yahoo.com

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Other research from Greece and Cyprus investigated augmented reality (AR) use in a teacher development program. Using a sample of 25 individuals involved in teaching STEM-related classes to lower-secondary students, the study concluded that they are the essential element in the AR design and material development process [14].

Also, a research team from Harvard explored how VR could be used as an immersive medium in authentic simulations in teaching ecosystems science using an inquiry-based curriculum and a blended-learning environment [15]. Also, blended environments allow students to become more engaged, leading to better academic achievement and understanding.

In conjunction with the COVID-19 pandemic, a unique set of challenges for educators around the world has developed [10]. In Thailand, educational institutions were subject to closure as a way to mitigate the spread of the virus. This meant that traditional teaching methods had to give way to online and distance learning systems in order to adapt.

The implication of this transition was that while theory-based instruction transitioned well to the new medium, students no longer had access to laboratory environments to perform educational experimentation exercises. It is for this reason that the authors wish to explore the relevance and implementation of 3-dimensional laboratory environments (3DVLs) as a means of replacing or augmenting the traditional laboratory experimentation model, both during COVID-19 and beyond.

Furthermore, at the secondary school level in Thailand, the majority of instructional emphasis is placed upon the application of existing theory as a problem-solving tool rather than understanding the origin of the equations. However, we see a positive correlation to student achievement when a variety of educational methodologies are implemented [16].

Although experimentation is highly beneficial for student engagement and overall retention of course material, many schools face budgetary constraints that preclude them from being able to purchase expensive lab equipment and experiment supplies, thus hampering the viability and repeatability of a wide variety of experiments.

Due to these constraints, teachers have had to restructure lessons to rely more heavily upon textbooks and theory than the associated hands-on laboratory activities. This moves the classroom further away from modern integrated learning strategies and as a result, less student engagement, enthusiasm, lower academic performance, and the alienation of students who benefit more strongly from a tactile or kinesthetic learning approach.

II. RESEARCH OBJECTIVES

To study the attitudes of education professionals towards the implementation of a 3-dimensional virtual laboratory environment (3DVL) in high school physics classes.

III. LITERATURE REVIEW

In this study of the attitudes of education professionals towards the implementation of a 3DVL for high school physics classrooms, the research team has taken the following under consideration:

A. Physics at the High School Level

A learner's conceptual understanding has been stated to be the primary goal of all education, with the desired outcome being their ability to apply their knowledge in daily life [17].

As a core science, the study of physics at the secondary school level is of supreme importance for learners who wish to continue and study science in their post-secondary education. Even where not compulsory, high school physics programs are nonetheless instrumental in teaching students scientific literacy skills that they will carry with them throughout their academic careers. In a physics classroom, teaching and learning improvements can come from computer-based training and 3DVLs.

Moreover, the quantity and quality of results from physics learning are influenced by many elements, two of which are how learning innovation and media are used [18]. Also, teachers acting as facilitators should be able to present learning media that helps students visualize abstract physics concepts.

However, although many initiatives are making progress, various studies also point out the many challenges of physics education in secondary schools, especially in developing countries. Reports contend that there is a lack of laboratory resources, science syllabuses are overloaded, and there is a chronic shortage of qualified science teachers [19], [20].

B. 3D Virtual Reality Laboratories (3DVL)

Computer Science and information communications technology (ICT) and early technology tools in education have transformed the way students learn and communicate [21], [22]. Moreover, laboratory activities play significant roles in science learning and the development of practical skills. Unfortunately, laboratories and their associated experiments are expensive but educators today can save effort, time, and money by implementing Internet-based virtual science labs (VSLs) [8], [23].

In Thailand, a research team studied how a virtual classroom learning environment (VCLE) could be used to enhance Thai university learners' creative thinking and their innovation enhancement in science, technology, engineering, arts, and math (STEAM) disciplines. It was determined that learner motivation to learn and innovation was increased [24].

3D is a media that can help promote learning in various fields as it is easy to understand quickly, allowing 360-degree views with better quality in promoting learning than traditional media [25]. Some authors have also elaborated on how online classrooms, e-learning, and technology are combined into what some refer to as a 'Smart Classroom' [26].

Another contributing factor to 3DVL use is that many schools have problems with equipment and material shortfalls in their science laboratories due to limited budgets and high science lab maintenance costs [23]. Therefore, 3DVL learning environments can be a mechanism to leapfrog funding issues and the significant lead times these processes entail. Also, with the onset of the COVID-19 pandemic and the near demise of the traditional classroom, online and remote teaching became a priority with an online virtual world a potentially significant solution to solving distancing and remote learning problems [27].

Therefore, technology and the full potential of digital classrooms have quickly become an integral part of modern education, with virtual classrooms providing many benefits to students and teachers. Virtual classrooms can also enhance the learning experience for everyone involved and offer a better quality education that benefits all students [28].

The use of technology in education also creates an exchange of skills and abilities, with learners better able to use their skills, knowledge, and abilities to their full potential. Additionally, teachers play an important role in creating teaching situations for students directly, so that students can develop analytical thinking skills (ATS).

In the time since distance learning was rolled out worldwide in an effort to fight the COVID-19 pandemic, the full potential of the digital classroom is quickly becoming realized. Virtual learning can provide many benefits for both students and teachers. While teachers benefit from a larger selection of organizational and evaluative tools to better tailor lessons to the needs of their pupils. Students benefit by being provided an enhanced learning experience that has been shown to have a positive effect on student satisfaction and engagement [29].

C. Teacher Needs Analysis

Each person's needs are continually changing over time due to the addition of more needs. Fortunately, estimating needs can be done through a systematic process of determining and addressing needs, or "gaps," between current conditions and the "gap". Therefore, the teacher needs analysis was undertaken by analyzing the *intended condition* (I) and *desired condition* (D) of the 44 teachers. Using a statistical analysis technique originating from [30], [31], the authors undertook a need analysis using the priority needs index (PNI) and its subsequent modified version ($\text{PNI}_{\text{Modified}}$) [32]-[35].

Other scholars have used a Meta-skills Development Needs Assessment Questionnaire and a $\text{PNI}_{\text{modified}}$ analysis to assess the needs and measure the gaps between current and desired states. In a study of 400 Bangkok public university undergraduate students in 2020, the authors stated that a needs assessment is a useful tool in the process of measuring the gaps between current and desired states and plays an essential role in the development of an individual's meta-skills in preparing students for the future [36].

In another study that examined Thai ‘Healthy Schools’ teacher professional competency needs development [37], the authors stated that needs assessment research is a systematic process to determine the difference between what currently exists and what is expected [38]. To evaluate the six teacher competency needs identified in the study, the authors used a $\text{PNI}_{\text{modified}}$ needs analysis ranking to determine their priority of needs [37].

In another study concerning elderly hypertension using a $\text{PNI}_{\text{modified}}$ analysis, it was determined that health responsibility, healthy eating, and social activity engagement were the greatest needs in maintaining one’s health as one grow older [39].

In yet another study where the assessment of needs was undertaken, a $\text{PNI}_{\text{modified}}$ analysis was used to determine the needs of 340 welfare school teachers [40], while another study examined the needs of 423 school administrators and teachers [41].

$\text{PNI}_{\text{Modified}}$ thus serves as a robust tool whose standard scores in the needs assessment calculates the differential value between the desired or intended outcome (I) and the actual desired results (D) [30]. The calculation formula used for the study was:

$$\text{PNI}_{\text{Modified}} = (I - D) / D \tag{1}$$

PNI = priority needs index
I = the mean for the desired outcome
D = the mean for the actual results or success

IV. RESEARCH METHODS

A. Population and Sample

The population used in this research was 486 science teachers in secondary schools in Thailand’s northeastern Surin Province in the academic year 2021. From this population, 44 physics teachers were selected using purposive sampling [42].

B. Research Instruments

The research instrument was a *Physics Teacher Opinion Questionnaire* concerning the actual conditions of their physics laboratories. It is a 5-level estimation scale according to Likert-type rating scales [43]. The questionnaire was synthesized from physics teaching theory and research [44]. This led to the development of a 41-item questionnaire concerning the teachers’ opinions on the use of 3DVL teaching media in physics teaching for 1) a mechanics laboratory, 2) an electromagnetism laboratory, and 3) a wave, sound, and light laboratory.

C. Instrument Validity Assessment

After the questionnaire’s design, each of the 41-items accuracy, consistency, and content validity were evaluated. Typically, a panel of experts is convened during which each item is examined and ranked. For this study, five experts were selected who all held PhDs and had been teaching physics for at least five years.

Using the commonly accepted index of item-objective congruence (IOC) [42], it has been suggested that any items with values ≤ 0.67 should be rejected or eliminated [45]. Therefore, after this process was completed, the survey contained 41 items whose average IOC value was 0.97.

D. Data Collection

The researchers started their data collection in March 2021 with 44 pre-selected physics teachers in Thailand’s Surin Province. Initial contact was made through social media and emails with follow-up contact made using telephone calls asking for assistance in providing information from each respondent. Thus, 44 complete questionnaires were returned from each of the targeted individuals.

E. Data Analysis

The study used descriptive statistics to evaluate the opinions of each teacher's input. These included both the mean and standard deviation (SD). Interpretation criteria for the 5-level scale use 4.50-5.00 as '5' (very high readiness), 3.50-3.49 as '4' (high readiness), 2.50-3.49 as '3' (moderate readiness), 1.50-2.49 as '2' (little readiness), 1.00-1.49 as '1' (no readiness).

F. Needs Analysis

The $\text{PNI}_{\text{Modified}}$ method was used to prioritize the needs and requirements from each of the teacher's inputs concerning the use of a 3D virtual laboratory (3DVL) [30], [31].

V. RESULTS

A. Teacher Respondents' Characteristics

Of the 44 individuals who participated in the study, the majority were female (61.39%), while 35 or 79.50% were titled 'teacher' and the remaining 20.50% were classified as 'coaches'.

Interestingly, 70.46% had an undergraduate degree, 27.27% had a Master's degree, and only 2.27% had a Ph.D. In terms of teaching experience, 45.45% had less than five years' experience, 29.55% had 2-10 years, while 25.00% had more than 10 years of teaching experience.

B. Actual Teacher Readiness to Teach in a Physics 3DVL

Table I shows the level of teachers' opinions about their actual level of readiness in teaching multiple topics in a 3DVL physics classroom.

TABLE I: TEACHERS' OPINIONS ABOUT THEIR ACTUAL READINESS IN TEACHING A 3DVL PHYSICS CLASSROOM

Physics Lab Procedure / Experiment	Physics Teacher Opinions		
	Mean	SD	A
The readiness of teaching in physics laboratories			
Actual readiness for teaching lab mechanics			
Measurement and measurement accuracy	3.27	1.06	M
Finding the speed of an object	3.13	1.00	M
Determination of g from free fall	3.15	1.07	M
Newton's laws of motion (air track)	3.15	1.03	M
Balance force	3.15	1.03	M
Determination of the coefficient of friction	3.04	1.03	M
Momentum and collision	3.00	0.98	M
Finding the relationship between work and energy	2.95	1.03	M
Torque	2.95	1.07	M
Simple harmonic motion	3.15	1.09	M
Simple pendulum motion	2.97	1.08	M
Horizontal circular motion	3.20	1.15	M
Determination of density and specific gravity	3.15	1.14	M
Determination of the viscosity of a liquid	3.09	3.13	M
Finding surface tension	3.13	1.23	M
Finding floating weight	3.11	1.22	M
The state of actual readiness averages	**3.09**	**1.20**	**M**
Actual readiness for teaching in electromagnet laboratories			
Using a multimeter and oscilloscope	2.86	1.11	M
Ohm's Law, series and parallel resistor circuits	2.93	0.94	M
Charging and discharging	2.79	1.13	M
Modification of the galvanometer to measure current potential difference and resistance	2.86	1.19	M
Using the Wheatstone Bridge diamond circuit to find unknown resistance	2.17	0.92	L
Determination of the electron e/m for the electron mobility in a uniform magnetic field.	2.56	1.08	M
Tangent galvanometer	2.59	1.08	M
Find the magnetic field generated by the electric current in the conductor	2.65	1.14	M
Current scale	2.68	1.17	M
Inductive current (Faraday's law)	2.61	1.14	M
Series and parallel RLC circuits in AC circuits	2.63	1.14	M
Resonance frequency in series and parallel RLC circuits determination	2.63	1.80	M
Generator	2.75	1.05	M
Transformer	2.86	1.11	M
The state of actual readiness averages	**2.68**	**1.14**	**M**
Actual readiness for teaching in wave, sound, and light laboratories			
Wave formation (wave tray)	2.93	1.20	M
Formation of standing waves in a rope/wire	2.90	1.15	M
Resonance in closed pipes	2.65	1.07	M
Overlapping waveforms using an oscilloscope	2.54	1.24	M
Finding the focal length of a lens	2.54	1.15	M
Parallax	2.40	1.14	L
Reflection of light in a medium	2.72	1.12	M
Light diffraction and diffraction grating	2.54	1.15	M
Light interference pattern	2.54	1.13	M
Spectral studies of hot gases	2.47	1.26	L
Polarization of light	2.47	1.19	L
The state of actual readiness averages	**2.61**	**1.16**	**M**

Note. A=actual readiness level, M = moderate readiness, L=little readiness

C. Desired Teacher Readiness to Teach in a Physics Laboratory

Table II shows the teachers' opinion levels concerning their desired readiness to teaching a 3DVL high school physics class.

TABLE II: TEACHERS' OPINIONS ABOUT THEIR DESIRED READINESS IN TEACHING A 3DVL PHYSICS CLASSROOM

physics lab	Physics Teacher Opinions		
	Mean	SD	D
Mechanics Laboratory Requirements			
Measurement and measurement accuracy	3.75	1.10	H
Finding the speed of an object	3.75	1.13	H
Determination of g from free fall	3.63	1.12	H
Newton's laws of motion (air track)	3.72	1.14	H
Balance force	3.63	1.14	H
Determination of the coefficient of friction	3.61	1.14	H
Momentum and collision	3.72	1.16	H
Finding the relationship between work and energy	3.75	1.18	H
Torque	3.56	1.26	H
Simple harmonic motion	3.70	1.11	H
Simple pendulum motion	3.70	1.17	H
Horizontal circular motion	3.79	1.40	H
Determination of density and specific gravity	3.67	1.13	H
Determination of the viscosity of a liquid	3.75	1.14	H
Finding surface tension	3.65	1.14	H
Finding floating weight	3.65	1.16	H
The state of desired readiness averages	**3.69**	**1.16**	H
Desired readiness for teaching in electromagnet laboratories			
Using a multimeter and oscilloscope	3.81	1.16	H
Ohm's Law, series and parallel resistor circuits	3.79	1.15	H
Charging and discharging	3.75	1.20	H
Modification of the galvanometer to measure current potential difference and resistance	3.68	1.15	H
Using the Wheatstone Bridge diamond circuit to find unknown resistance	3.45	1.20	H
Determination of the electron e/m for the electron mobility in a uniform magnetic field.	3.54	1.19	H
Tangent galvanometer	3.54	1.16	H

Find the magnetic field generated by the electric current in the conductor	3.65	1.14	H
Current scale	3.59	1.14	H
Inductive current (Faraday's law)	3.65	1.16	H
Series and parallel RLC circuits in AC circuits	3.61	1.18	H
Resonance frequency in series and parallel RLC circuits determination	3.59	1.24	H
Generator	3.59	1.22	H
Transformer	3.65	1.25	H
The state of desired readiness averages	**3.64**	**1.18**	H
Desired readiness for teaching in wave, sound, and light laboratories			
Wave formation (wave tray)	3.75	1.18	H
Formation of standing waves in a rope/wire	3.75	1.18	H
Resonance in closed pipes	3.79	1.19	H
Overlapping waveforms using an oscilloscope	3.54	1.17	H
Finding the focal length of a lens	3.71	1.43	H
Parallax	3.56	1.14	H
Reflection of light in a medium	3.75	1.10	H
Light diffraction and diffraction grating	3.72	1.18	H
Light interference pattern	3.72	1.18	H
Spectral studies of hot gases	3.70	1.15	H
Polarization of light	3.65	1.11	H
The state of desired readiness averages	**3.69**	**1.18**	H

Note. D=desired readiness level, H = high readiness

D. *Needs Ranking in Teaching in a VR Physics Laboratory*

Table III shows the teacher opinion levels concerning their priority needs rankings in teaching a 3DVL Thai high school physics class.

TABLE III: TEACHERS' PRIORITY NEEDS IN TEACHING A 3DVL PHYSICS CLASSROOM

The needs assessment of teachers teaching physics 3DVL				
Teacher needs assessment in teaching lab mechanics				
	M	**SD**	**O**	**PNI**
Measurement and measurement accuracy	3.27	3.75	41	0.15
Finding the speed of an object	3.13	3.75	31	0.20
Determination of g from free fall	3.15	3.63	39	0.15
Newton's laws of motion (air track)	3.15	3.72	34	0.18
Balance force	3.15	3.63	39	0.15
Determination of the coefficient of friction	3.04	3.61	32	0.19
Momentum and collision	3.00	3.72	27	0.24
Finding the relationship between work and energy	2.95	3.75	25	0.27
Torque	2.95	3.56	29	0.21
Simple harmonic motion	3.15	3.7	35	0.17
Simple pendulum motion	2.97	3.7	26	0.25
Horizontal circular motion	3.20	3.79	33	0.18
Determination of density and specific gravity	3.15	3.67	38	0.17
Determination of the viscosity of a liquid	3.09	3.75	28	0.21
Finding surface tension	3.13	3.65	37	0.17
Finding floating weight	3.11	3.65	36	0.17
Teacher needs assessment in teaching in electromagnet laboratories				
Using a multimeter and oscilloscope	2.86	3.81	18	0.33
Ohm's Law, series and parallel resistor circuits	2.86	3.79	20	0.33
Charging and discharging	2.93	3.75	23	0.28
Modification of the galvanometer to measure current potential difference and resistance	2.79	3.68	21	0.32
Using the Wheatstone Bridge diamond circuit to find unknown resistance	2.86	3.45	30	0.21
Determination of the electron e/m for the electron mobility in a uniform magnetic field.	2.55	3.54	10	0.39
Tangent galvanometer	2.56	3.54	12	0.38
Find the magnetic field generated by the electric current in the conductor	2.59	3.65	8	0.41
Current scale	2.65	3.59	17	0.35
Inductive current (Faraday's law)	2.68	3.65	16	0.36
Series and parallel RLC circuits in AC circuits	2.61	3.61	11	0.38
Resonance frequency in series and parallel RLC circuits determination	2.63	3.59	15	0.37
Generator	2.63	3.60	14	0.37
Transformer	2.75	3.65	19	0.33
Teacher needs assessment in teaching in wave, sound, and light laboratories				
Wave formation (wave tray)	2.93	3.75	23	0.28
Formation of standing waves in a rope/wire	2.9	3.75	22	0.29
Resonance in closed pipes	2.65	3.79	7	0.43
Overlapping waveforms using an oscilloscope	2.54	3.54	9	0.39
Finding the focal length of a lens	2.54	3.71	6	0.46
Parallax	2.4	3.56	2	0.48
Reflection of light in a medium	2.72	3.75	13	0.38
Light diffraction and diffraction grating	2.54	3.72	5	0.46
Light interference pattern	2.54	3.76	3	0.48
Spectral studies of hot gases	2.47	3.7	1	0.50
Polarization of light	2.47	3.65	4	0.48

Note. M=mean, SD=standard deviation, O=order of needs

VI. DISCUSSION

From the analysis of the 41 3DVL items presented to each teacher for their opinions, the following discussion is presented on each teacher's actual and desired needs and then their needs are ranked in order.

A. *Actual Teacher Readiness to Teach in a Physics Laboratory*

Table I's analysis results from the 41 items determined that the physics teachers' *actual readiness* for teaching lab mechanics was overall moderate but the highest of the three sections evaluated (mean=3.09, SD=1.20). This indicated that the teachers felt their actual ability, preparation, and lab equipment were moderately appropriate to take on the challenges of teaching a 3DVL physics class.

Specifically, three items were ranked highest. These were the teacher's ability to teach the concepts of *determining g from free fall* (mean=3.15, SD=1.07), *Newton's laws of motion (air track)* (mean=3.15, SD=1.03), and *balance force* (mean=3.15, SD=1.03).

B. *Desired Teacher Readiness to Teach in a Physics Laboratory*

Table II's analysis results from the 41 items determined that the physics teachers *desired readiness* for teaching lab mechanics was overall *high*, with their desired readiness for teaching lab mechanics (mean=3.69, SD=1.16) and their desired readiness for teaching in wave, sound, and light laboratories (mean=3.69, SD=1.16) similar in importance (mean=3.69, SD=1.18).

Of the 41 items surveyed, *using a multimeter and oscilloscope* were determined to be ranked most importantly desired by the teachers (mean=3.81, SD=1.16). This was followed by three items judged to be of equal importance. These were the desired ability to teach *horizontal circular motion* (mean=3.79, SD=1.40), *Ohm's Law, series and parallel resistor circuits* (mean=3.79, SD=1.15) and *resonance in closed pipes* (mean=3.79, SD=1.19).

C. Needs Ranking in Teaching in a VR Physics Laboratory

From the results from Table III's analysis of each teacher's 'order of needs,' it was determined that the teaching ability for the *spectral studies of hot gases* was the highest need (1), this was followed by teaching *parallax* (2) which is an astronomical concept related to an object's observed displacement caused by changes in the observer's location. Next was the need to teach *light interference patterns* (3), the *polarization of light* (4), and then *light diffraction and diffraction grating* (5).

Speculation concerning this needs order comes from the high cost of experimental kits and the loss, especially of the fragile hot gas spectra, as well as the appearance of the grating plates to be thin materials.

D. Supporting International Studies

These findings from this study are supported by various other global studies which also explored the use of 3DVLs in science and physics classrooms. In one study from *Dublin, Ireland*, the experimental 3DVL group of secondary school students experienced higher user experience scores while also finding the application enjoyable wishing to participate in its use more often [23]. In *Indonesia*, a research team used 3DVL to teach physical optics across five high schools in Semarang City and determined that the software used across a spectrum of users was excellent which allowed students to easily comprehend difficult and abstract concepts [46].

This need for 3DVLs in physics teaching is also supported by another study from *Colombia* in which the researchers used the Unity platform to create multiple 3D tutorials on physics concepts [47]. The 3DVL was also stated to be a highly useful tool due to limited physics teaching laboratory availability, lack of materials, lack of qualified staff, and the students' difficulty in seeing abstract physics concepts.

In the *Republic of China (Taiwan)* the research team created a 3D teaching model during the COVID-19 epidemic for teaching physics using a classroom virtual reality (VR) teaching kit [27]. The findings confirmed that 3DVLs can positively affect students' attitudes when it comes to physics and improve their understanding of physics concepts. It was also confirmed that 3DVLs are suitable tools for teaching physics experiments.

In *Turkey*, a research team set out to determine how teachers perceived VR use in the classroom after three weeks of classroom training and two months of classroom teaching [48]. From the interview findings, they reported that VR classroom use captured the interest of the students while increasing their creativity and motivation. It also allowed the students to make virtual trips while improving their technology literacy, individualized learning, and understanding of complex concepts.

Favorable teaching opinions concerning 3DVLs was also determined in a study from *Singapore* [49], while in *Morocco* the authors stated that 3DVL use improves student performance [50]. Additionally, similar findings were found in Oman in which the authors stated using 3DVLs in teaching contributed to student success in learning physics and higher achievement, which led to increased learner participation and motivation [51].

The use of 'Smart Classrooms' (SC)has also been widely explored, which according to [52] is a physical classroom in which advanced forms of educational technology are used including artificial intelligence sensors [53]. Studies have reported that SCs exceed traditional classroom experiences as they combine both the physical and virtual worlds [52]. They are technologically rich with information and communication technology (ICT) digital tools, learning resources, and interaction support for various teaching and learning activities. These include personalized learning, group learning, inquiry-based learning, collaborative learning, mobile learning, and virtual learning [54].

The SC is also a warehouse for data, which can collect, sort, compute, and analyze student data in order to make optimized pedagogical decisions. Other studies have also determined that an SC environment can stimulate students' learning motivation, promote active learning, and improve academic performance in middle school science education [55].

Finally, in Saudi Arabia, virtual science laboratories were found to be exciting and useful during their student trials allowing students to do multiple times as needed with no additional costs [8].

VII. CONCLUSION

The study set out to examine the actual and desired needs of Thai physics teachers from a sample of 44 individuals in Thailand's northeastern Surin Province. Also, the assessment was undertaken concerning each teacher's 'order of needs' from the 41 items presented for evaluation to the teachers.

Moreover, there were three main categories in the study's assessments. These were the teachers' opinions on the use of 3DVL teaching media in physics for, 1) a mechanics laboratory, 2) an electromagnetism laboratory, 3) and a wave, sound, and light laboratory.

The results of the study can be summarized with the following key points. Physics teachers believed that the overall readiness in teaching and learning management of the three groups of physics laboratories was at a moderate level. They also commented that the need for computer-assisted teaching materials and 3DVL science and physics laboratories for high school students was at a high level in all three categories.

Concerning each teacher's 'order of needs,' it was determined that the top five teaching needs were for the *spectral studies of hot gases* (1), followed by teaching *parallax* (2), the need to teach *light interference patterns* (3), the *polarization of light* (4) and then *light diffraction and diffraction grating* (5).

VIII. SUGGESTIONS AND LIMITATIONS

With the onslaught of the global COVID 19 pandemic beginning in early 2020, educational institutions had to find methods to move education out of the traditional classroom into an online world. Countless studies have now been done on pedagogies that can be used to do this including flipped classroom, blended learning, distance learning television, and now quickly growing in popularity, 3DVLs in science and physics education.

When teachers combine smartphones with tools such as Google Cardboard for use in teaching using 3DVL, simplicity and low cost can be achieved. Numerous studies have showcased how teachers have developed their own 3D applications and successfully implemented them into their school system's educational process. Also, VR applications and their development can create opportunities for university and TVET student recruitment and real-world learning processes and potential entrepreneurial opportunities.

However, limitations to future 3DVL implementations include funding and software/equipment sourcing through the traditional school budgetary process which can potentially entail long periods. The study was also limited in the size of the sample group and geographically constrained as it was from a single Thai province.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

The authors confirm contributions to the paper as follows: study conception and design: Choojit Sarapak and Surat Sukman. Data collection: Choojit Sarapak, Jutamas Yoomark, Jutapol Jumpatam, Oranuch Nakchat, Khunapat Sonsrin, and Prayut Kong-In. Analysis and interpretation of results: Choojit Sarapak and Surat Sukman. Draft manuscript preparation: Choojit Sarapak and Surat Sukman. All authors reviewed the results and approved the final version of the manuscript.

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Choojit Sarapak is a science educator/physics lecturer within the Faculty of Science and Technology at Surindra Rajabhat University in Surin Province, Thailand. She specializes in science (physics and mathematics) teaching and studying the ways technology can be used to promote student interest in STEM (science, technology, engineering and mathematics). Prior to my current position, for 15 years I was a visiting scholar in nanotechnology education at the Department of Engineering at the University of Wisconsin, Madison and the Department of Science and Art at Harvard University in Cambridge, Massachusetts. She has taught physics/fundamental science to a large cross-section of university students, including non-science students to science students. She has also led a number of professional development activities for science in-service and pre-service teachers and university faculty.

Surat Sukman is a computer lecturer within the Faculty of Management Sciences at Surindra Rajabhat University in Surin Province, Thailand. His doctoral and education specialization is in computer programming, the Internet of things (IoT), mobile applications, and is currently teaching computer programming to business computer university students.

Prayut Kongin is a physics lecturer within the Faculty of Science and Technology at the Surindra Rajabhat University in Surin Province, Thailand. He received a master' degree in science education (physics) from Srinakharinwirot University in Songkha, Thailand and a bachelor's degree in physics education from Mahasarakarm University in Thailand. He specializes in electromagnetism, model physics and nuclear physics. He has 25 years of teaching in higher education and is currently serving as the Dean of the Faculty of Science and Technology at Surindra Rajabhat University and an assistant professor in physics. His current research interest is the development of physics teachers and students using experiential- based learning.

Khunapat Sonsrin is a science educator/biology lecturer within the Faculty of Science and Technology at the Surindra Rajabhat University in Surin Province, Thailand. She specializes in science and biology) teaching and studying ways of using technology to promote student interest in STEM (science, technology, engineering and mathematics). She has also served as a visiting scholar in the Science Education Group in the Department of Education at Washington State University in Pullman, WA, USA. She has also taught physics and fundamental science for students from multiple backgrounds and interests. She has also led a number of professional development activities for science in-service and pre-service teachers and university faculty.

Oranuch Nakchat is an assistant professor and biochemistry/chemistry lecturer within the Faculty of Science and Technology at the Surindra Rajabhat University in Surin Province, Thailand. She specializes in silk product development and dyeing using natural materials.

Jutapol Jumpatam is a science educator/physics lecturer within the faculty of science and technology. He specializes in science (based on physics and material science) teaching and study in physical properties and characterizations of materials.

Jutamas Yoomark is an assistant professor in the Faculty of Science and Technology at Surindra Rajabhat University in Surin Province, Thailand. She specializes as a science educator and biology lecturer.