LONG DISTANCE LAB AFFAIRS: PHYSICS ACHIEVEMENT AND METACOGNITION EFFECTS OF DISTANCE LABORATORIES IN A SENIOR HIGH SCHOOL IN THE PHILIPPINES

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ABSTRACT

Due to the necessity to continue learning even during the pandemic, schools opened utilizing distance learning modalities. However, there is a dearth of evidence on the effectivity of this modalities in physics. In this study, we investigated the effects of three physics distance learning modes; the module-only (MO), virtual lab plus module (VLM), and the physical lab plus module (PLM) classes in physics achievement and metacognition employing the pretest-posttest and repeated measures research designs. All learning modules used were in digital formats sent through free messaging platforms. Analysis of data includes paired samples t-test, one-way ANOVA, repeated measures ANOVA, and independent samples t-test. Results revealed that all three distance learning modes have significantly higher post-test than pre-test scores. Further analysis showed, however, that only VLM had significantly higher gain scores than MO. Initially, at pre-MO and post-MO administrations, male students had significantly higher metacognition but this diminished after they perform both virtual and physical labs. It was in post-PLM where students have significantly better metacognition than pre-MO and post-MO. This study showed that not only do physical and virtual labs supplement distance modular learning, they are also complementary that both must be used in distance learning.

Keywords: Distance learning, distance physical lab, distance virtual lab, distance physics lab, modular distance learning, metacognition, physics achievement.

INTRODUCTION

Delivery of education in the world is put into test when the pandemic caused by COVID-19 spread across the globe in the early part of year 2020. Billions of students across many countries were affected. Classes in Philippine basic education that usually concludes late March or early April were forced to end, mostly without final exams. No classes of any sort were conducted for several months until the Department of Education (DepEd) drafted its Basic Education Learning Continuity Plan (BE-LCP). Here, the department in-charge of the country's basic education concluded that schools must open due to the risks marginalized children face as school disruptions continue such as the increasing likelihood of their not going back to schools. However, only distance learning modes are allowed due to government restrictions on any gatherings. Choices can be classified into online, modular, homeschooling or combinations thereof. Most public schools opted for printed modular learning mode due to learners' lack of internet connectivity and computers (DepEd 2020).

Distance learning, although argued to be different with distance education by various authors (e.g. (Cropley and Kahl 1983; Holmberg 1989; King et al. 2001), will be treated as the same in this study. Both will be described as an "umbrella" term for all learning modes where teachers and learners are separated in space (Holmberg 2005). Such learning may be done through TV or radio, printed materials, telephone or through internet. Distance learning have vast history of practice that can be traced back more than a hundred years ago (Spector et al. 2014). Although, in earlier times, it was criticized to be slow and ineffective because then, correspondence were through postal offices (Bernard et al. 2009). On the other hand, printed modular distance learning being used by most Philippine public schools involves the giving of printed modules to learners to which they will study and answer at home for a week. Parents receive and return modules in schools at some scheduled day usually every Monday.

The Senior High School (SHS) department in Aurora State College of Technology (ASCOT) employed a slightly different approach called digital modular distance learning (DMDL). Electronic copy in static PDF format of modules is sent to students through free messaging platforms to which they can download and answer in a week. Answers are accepted in any form, but students send pictures of their handwritten or encoded works through the same media. Because teaching and learning happens through electronic means, a cellphone, a laptop or a desktop, this mode may also be called e-learning (Guri-Rosenblit and Gros 2011). One major difference between DMDL and e-learning is the use of learning management systems where lessons are viewed, and outputs are uploaded by the students. Use of such systems may be more superior in several ways except that DMDL is a lot less costly as it uses less internet data for connection – an important consideration because ASCOT SHS is populated mostly by students that belong to families with low income (Padios et al. 2021). On the other hand, if online learning is implemented to students from low-income families, they may not like it not because of its quality but because of its affordability and accessibility causing them to have negative perceptions which will affect their learning satisfaction (Dastidar 2021). Although nothing in the literature yet had studied our version of digital modular distance learning, some studies on e-learning demonstrated effectiveness in distance learning (e.g. Encarnacion et al., 2021; Iancu et al., 2021). Hence, even with a seemingly unexplored learning mode, hopes were taken from almost similar proven ones.

However, some subjects just need laboratory activities for a more effective instruction, one of these is physics. It is just difficult to teach physics without lab because during face-to-face (F2F) or in-person classes, use of lab in instruction resulted to positive results in terms of science achievement as well as attitude towards science (Wang et al., 2015; Wen et al., 2020; Xu et al., 2020, and; Zacharia & Olympiou, 2011). Therefore, it is but imperative that alternative for F2F labs be tried.

Solutions to distance physics labs can be in the form of hands-on distance lab or take-home lab, remote lab, and computer simulation or simply virtual lab. Hands-on distance lab involves physical experimentation but done at home. Impact of hands-on distance lab were found to be no different from hands-on F2F lab but students in the distance lab feel that what they do is less scientific (Moosvi, Reinsberg, and Rieger 2019). Remote lab involves manipulation of equipment that is in school, or other laboratories, by students studying at home via the internet. Such labs employed in the past have demonstrated good results in the teaching and learning process (Heradio et al., 2016; Morales-Menendez et al., 2019, and; Viegas et al., 2018). However, aside from being expensive and complicated, these labs were also employed in higher education institutions specializing in engineering courses whose students are expected to be computer program literates, it is their trade. Finally, use of computer simulations or simply virtual lab involves manipulation of objects in a computer program that simulates what happen in real life. Studies that explored the effectivity of virtual lab showed that it is at least equal to or better than a physical lab (e.g. Puntambekar et al., 2021; Pyatt & Sims, 2012). These studies however were employed in an F2F classroom setting under the direct supervision of a teacher. In a learning mode during the pandemic, learning environment as well as work dependence had changed, hence the interest of the current study.

Several studies have measured the effectiveness of doing labs in the past and the most common measure is the students' achievement scores (e.g. Hamed & Aljanazrah, 2020; Wan Ab Kadir et al., 2021). This directly tells us how much was learned through a laboratory intervention compared to some control treatment, usually traditional practices. Coupled with achievement is also the measure on the changes of students' attitudes after going through a proposed lab (e.g. Fox et al., 2021; Van De Heyde & Siebrits, 2019). Such practice of monitoring changes in students' attitude is as important with achievement because it also matters when one enjoys learning. Fast growing measures after lab instruction are changes in students' learning constructs such as metacognition and self-efficacy (e.g.Carpendale & Cooper, 2021; Haeruddin et al., 2020; Jones et al., 2021; Salar & Turgut, 2021). Metacognition, mostly defined as one's "ability to think about its own thinking," is the learners' awareness and control in their ways of understanding. The importance of this construct relies on the hope that learning can be improved with students of any cognitive level (Thomas and McRobbie 2001). On the other hand, self-efficacy is a "person's particular set of beliefs that determine how well one can execute a plan of action in prospective situations" (Bandura 1977). A high self-efficacy in learning physics for instance enables learners to believe they can grasp even the hardest concepts. Later studies have also demonstrated how self-efficacy predicts science achievements (Sagun and Prudente 2021). Both self-efficacy and metacognition are measured in an instrument called self-efficacy, metacognition, and learning inventory in science (SEMLI-S) developed by G. Thomas et al. (2008), in this study shall only be termed metacognition. The current study is then steered towards evaluating the effects of distance learning modes on physics achievement scores and metacognition.

PURPOSE OF THE STUDY

During the course of learning under the pandemic, universities and schools have realized the power of distance education, not only as a remedy for emergency in education, but also as a conscious choice for learning. Since laboratory experimentation is an integral part of teaching physics (American Association of Physics Teachers 1998), the current study is then aimed to evaluate the effectiveness of distance learning initiatives which includes distance physical and virtual lab in learning early lessons in General Physics I of ASCOT SHS students in Science, Technology, Engineering and Mathematics (STEM) strand, i.e. kinematics, and the laws of motion. In response to the growing call for equality among sexes, and because many researchers reported attitude and achievement gap between this group (e.g. Espinosa et al., 2019; Stoeckel & Roehrig, 2021), scores of male and female students shall also be compared to decide whether these distance learning initiatives give equal opportunities. Specifically, this study aims to:

1. Determine if there is a significant difference in the physics achievement of SHS STEM students when exposed in the following distance learning modalities:
   1.1. Module-only class (MO)
   1.2. Distance virtual laboratory plus module class (VLM)
   1.3. Distance physical laboratory plus module class (PLM)
2. Determine if there is a significant difference in physics achievement of male and female SHS STEM students when exposed in the different distance learning modalities.
3. Determine if there is a significant difference in the physics learning metacognition of SHS STEM students when exposed in the following distance learning modalities:
   1.1. Module-only class (MO)
   1.2. Distance virtual laboratory plus modular class (VLM)
   1.3. Distance physical laboratory plus modular class (PLM)
4. Determine if there is a significant difference in physics learning metacognition of male and female SHS STEM students exposed in the different distance learning modalities.

METHODS

To measure the effects of each distance learning modalities being investigated, the Module Only (MO), Virtual Laboratory plus Module (VLM) and Physical Laboratory plus Module (PLM), we employed the pretest-posttest and repeated measures research designs. Although with threats to validity, pretest-posttest research design is employed t'o test the effectiveness of a teaching intervention due to some of its strengths such as its being cost-effective and it addresses ethical issues in learners' assignment of treatment or control (Tan-lei and Zhu 2018). Repeated measures, on the other hand, is appropriate when comparing two or more teaching strategies on the same students (Salkind 2010). Figure 1 shows the conceptual framework of the study where Physics Achievement was measured by three different Physics Achievement Tests (PAT) while Metacognition was measured by the Self-efficacy, Metacognition and Learning Inventory in Science (SEMLI-S).

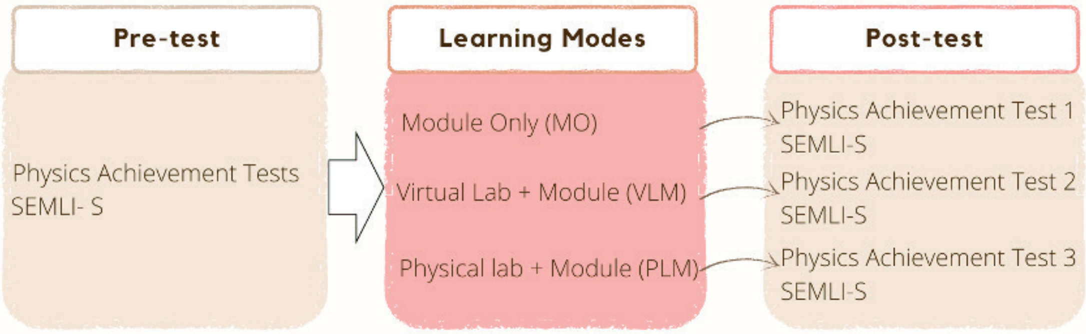

Figure 1. The conceptual framework of the study

Learning modules being referred to in this study are in the form of static PDF following an inquiry-based learning. These modules are sent to students via messaging platforms every Monday. Scheduled sending of modules like this is highly advantageous to students as they can plan to buy mobile data subscriptions once in a week. They can buy the cheapest subscription that ranges from Php 30.00 to Php 50.00 (USD0.60 to USD1.00). Guided inquiry approach was used in both laboratory activities. Students were only given a "challenge prompt." One example of a challenge prompt during the virtual laboratories was "Discuss factors affecting the range of a projectile." During physical laboratory, one challenge prompt used was "What happens when a force is applied slowly? quickly?" The module was a self-learning module developed by the physics teacher, who is also the first author, following the format: Activity, Discussion, Input, Application, Synthesis, and Evaluation.

Physics lessons covered were in kinematics and the laws of motion in dynamics. Under MO, the topics covered were uniform motion and accelerated (both horizontal and free fall) motion. Projectile motion and the law of acceleration were covered in the VLM while in PLM, the laws of inertia and interaction. The whole duration of the study lasted for almost three months.

Participants

This research was conducted during the pandemic caused by the corona virus disease 2019 (COVID-19) at the Senior High School (SHS) department of Aurora State College of Technology (ASCOT) where the only mode of classes possible is a distance learning. ASCOT SHS is in the province of Aurora located at 15.7336° N, 121.5713° E. Aurora is geographically north of Luzon but in territory belongs to Central Luzon or Region III in the Philippines. Currently inhabited by more than 235 000 Filipinos, Aurora is a rural community in the foot of Sierra Madre Mountain ranges and along the coast of the Pacific.

Grade 12 Science, technology, engineering, and mathematics (STEM) students who are taking General Physics I were the participants in this study. All students initially participated, however, out of 32, one of them dropped-out of the roll due to online game distractions while another was not able to answer and submit modules until late in the semester. There was a total of 30 willing and volunteer participants: 19 of them are male while 11 are female. A letter, a confidentiality statement and a consent form explaining the content of the research and voluntary participation were signed by both parents and students.

Research Instruments

The modules used followed the "Activity, Discussion, Input, Application, Synthesis, and Evaluation" format. Preliminary phases of the module are meant for discovery of knowledge using an inquiry approach. All answers for each activity are provided except for the evaluation part. Each module used was subjected for content and grammar critiquing by professors at the same college.

Metacognition as a learning theory does not influence learning alone (Thomas and McRobbie 2001). Learning is influenced by metacognition together with other constructs thus, an instrument must encompass these considerations. An instrument called Self-efficacy, Metacognition and Learning Inventory – Science (SEMLI-S) developed by G. Thomas et al. (2008) fits this criteria, hence its adaptation with permission in the current study. The only change in inventory is that "science" is changed into "physics." The inventory composed of 30 statements: five statements for learning risks awareness (e.g. "I am aware of when I am about to have a learning challenge."), seven for cognitive connectivity (e.g. "I seek to connect what I learn in my life outside of class with science class."), three for control of concentration (e.g. "I adjust my level of concentration depending on the difficulty of the task."), nine for monitoring, evaluation and planning (e.g. "I stop from time to time to check my progress on a learning task.") and six stems for self-efficacy (e.g. "I believe I will receive an excellent grade in this course.").

Achievement in physics was measured by a teacher-made test called Physics Achievement Test (PAT). There were three PATs used: PAT1 for uniform motion and uniformly accelerated motion, PAT2 for projectile motion and law of acceleration and PAT3 for the laws of inertia and interaction. Multiple choice questions from each PATs were selected from the summative tests given to STEM students for the past three years. The criteria used in choosing the questions were (1) higher order thinking level of questions from Bloom's Taxonomy of Objectives, (2) difficulty index that ranges from 0.30 to 0.70, and (3) the average difficulty must be approximately equal across each PATs. Given these criteria, 25 questions for each PAT were chosen with a difficulty index of 0.34 to 0.65. PAT1 had an average difficulty index of 0.486, PAT2 with 0.493 while PAT3 had 0.478. Analysis of variance showed no significant differences with these indices hence, the three tests had statistically equal difficulty. Questions were subjected for construct validity test by a professor in the education department. After carrying out the suggestions, the physics achievement test was finalized.

Data Collection and Analysis

All PATs and the SEMLI-S were pre-tested before classes started. First two lessons were measurement and vector quantities delivered in modular format, this can be regarded as the "getting-to-know" phase. Only after students finished studying two more modules which contain uniform motion, acceleration and free-fall motion was the PAT1 and SEMLI-S post-tested.

Participating students were trained on how to conduct laboratory activity using the guided inquiry approach. First, a video tutorial prepared by the teacher was sent to them. The next day, a sample challenge prompt was given which they will answer by conducting a virtual laboratory using an appropriate PhET interactive simulations, a freeware downloadable for both computers and android phones. They were asked to write down the procedures they did, present the data they gathered in a table or graph, interpret it then provide a conclusion which should answer the challenge question. Their papers were checked and commented on. On the third day, the instructor showed two possible ways to experiment (this serves as the "answer key" for the sample prompt), present the data and drew conclusion in the given exercise. It was on their second attempt that most of them mastered doing an experiment without a procedure, only a challenge prompt. Still, the teacher showed possible ways on how to conduct the experiment and prepare a laboratory report.

After the training, the first challenge prompt included in this study was sent which they answered by experimenting using the appropriate PhET interactive simulation. They had to send their laboratory report first before they receive their module. There were two challenge prompts they answered for two weeks: one for projectile motion and another for law of acceleration. After these lessons, PAT2 and SEMLI-S were administered.

On the third and fourth challenge prompt, students had to answer by experimenting with real objects. Some assistance such as providing hints and answering questions were provided here by the instructor as some of them had difficulty innovating and designing experiments. Laboratory reports still followed the same format and means of submission. However, the teacher required that evidence for the conduct of the experiment such as a video or a picture must accompany the lab report. After receipt of each report, modules were sent for them to study. Finally, PAT3 and SEMLI-S were administered.

The results of each PAT and SEMLI-S were tabulated and analyzed, measures of central tendency and standard deviations were calculated. PAT results were analyzed using paired samples t-test for the significant differences between pretest and posttest scores in each distance learning. For additional insights from this dataset, we also analyzed gain scores using one-way analysis of variance. Comparison of physics achievement gain scores between male and female participants was performed using independent samples t-test.

SEMLI-S data was analyzed using a one-way repeated measures ANOVA; Bonferroni post-hoc analysis was performed to further inspect significant differences between each learning mode. Finally, comparison between SEMLI-S scores of male and female participants were performed using the independent samples t-test.

FINDINGS

This study aimed to determine the effects of each distance learning modalities on students' physics achievement scores and metacognition. We administered all pretests during the very first day of class opening then posttest after a conduct of each learning mode. During the first four weeks, classes were purely modular (MO). On the sixth and seventh week, MO classes were preceded by a conduct of virtual labs. On the ninth and tenth week, it was preceded by a conduct of experimentations with real objects. This process is presented in table 1. Data gathered were analyzed and the results are presented in this chapter.

Table 1. Weekly activities and the administration of instruments.

Week		Activities	Tests
1	Orientation	Obtained Parents' Consent General class orientation	Pre-test: Physics Achievement Tests SEMLI-S
2	Training	Training on: conduct of lab writing of lab report	
3	MO	Learning through modules	
4		Learning through modules	
5			Post-test: PAT1 and SEMLI-S
6	VLM	Virtual lab then modules	
7		Virtual lab then modules	
8			Post-test: PAT2 and SEMLI-S
9	PLM	Physical lab then modules	
10		Physical lab then modules	
11			Post-test: PAT3 and SEMLI-S

Physics Achievement

Result of comparing the mean percentage scores (MPS) between pretest and posttest across each learning modalities are presented in table 1. All distance teaching techniques used during the entire study resulted to a statistically significantly higher posttest scores than pretest scores. The teacher-written modules when used alone and when coupled with distance virtual and physical labs are effective in learning physics. However, based on Philippine's Department of Education standard of mastery (DepEd 2012), module-only classes did not show improvement for the test scores where both were only at "average mastery" level. On the other hand, VLM classes improved from "average mastery" to "moving towards mastery" while PLM classes improved from "low mastery" to "moving towards mastery" both implying that investigated distance physics instruction (DMDL) is better when accompanied with distance laboratory experimentations.

Table 2. Comparison between pretest and posttest scores across different learning modalities.

Learning Mode		MPS	Level of Masterya	Std. Deviation	Std. Error Mean	t	Sig. (2-tailed)
MO	Pre-test	39.38	Average Mastery	10.315	1.883	-7.74**	0.000
	Post-test	62.47	Average Mastery	11.383	2.078		
VLM	Pre-test	37.83	Average Mastery	9.885	1.805	-15.67**	0.000
	Post-test	72.33	Moving towards Mastery	10.646	1.944		
PLM	Pre-test	33.00	Low Mastery	14.89	2.719	-9.07**	0.000
	Post-test	65.83	Moving towards Mastery	13.728	2.506		

*Note: **p<.01, [a]Levels of Mastery: Mastered (96-100), Closely approximating mastery (86-95), Moving towards mastery (66-85), Average (35-65), Low (15-34), Very low (5-14), Absolutely no mastery (0-4)*

To compare the three distance learning modes investigated, we performed an analysis of gain scores. One-way analysis of variance for gain scores showed that at least one learning mode had better gain scores over the other modes $F(2,87)=4.247$, $p=.017$. Post-hoc analysis using Tukey's HSD, as recommended for one-way ANOVA (Kirk 2013), is presented in table 2. Here, only the digital modular distance learning (DMDL) coupled with distance virtual labs (here called VLM) using appropriate phet interactive simulations showed significantly higher gains scores than the lone use of modules for learning.

Table 3. Tukey's HSD post-hoc analysis of gain scores.

Learning Mode (I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
MO	VLM	-11.416*	4.232	0.023	-21.506	-1.325
	PLM	-9.749	4.232	0.061	-19.839	0.342
VLM	PLM	1.667	4.232	0.918	-8.423	11.757

*Note: * Significant at p<.05*

Respondents' Sex and Physics Achievement

We performed independent samples t-test to compare gain scores between male and female participants, the results are presented in table 3. Comparison showed no statistically significant difference among the gain scores of male and female participants which implies that all distance learning modalities used were gender fair when it comes to physics achievement, a fast-growing consideration in teaching that aims to provide equal chances for both sexes to learn.

Generally speaking, females outperform males in schools (Maligalig and Albert 2008; Voyer and Voyer 2014) and sometimes even in physics achievement (Collado 2019; Constante and Agsalud 2019; Yerdelen-Damar and Pesman 2013). However, other studies also point in opoosite direction as girls' achievement scores in physics wane and tend to be outperformed by boys (Krakehl and Kelly 2021; Lubinski and Benbow 1992; Taasoobshirazi and Carr 2008) probably due to girls being less interested in this field of science than boys (Adams et al. 2006; Hoffmann 2002; Murphy and Whitelegg 2006; Robertson et al. 2010). Sex differences in cognitive understanding exist (Halpern 2014)due to differences in abilities such as spatial, memory as well as language and mathematical abilities (Halpern 2014). Collado (2019) on the other hand demonstrated this sex differences in physics achievement may be closed by training girls with spatial ability. Additionally, achievement gap among sexes also varies across and within nations (Miller and Halpern 2014; Stoet and Geary 2013) due to differences in culture and gender equity scores. Thus, it is not surprising for the current study to result into equal achievement scores among sexes similar to other studies (Gambari et al. 2013; Long and Jiar 2014)

Table 4. Statistics on comparisons of PAT gain scores between male and female participants.

Learning Modes	Sex	N	Mean Gain Score	t	Sig.
MO	Male	19	24.628	$-.674^{ns}$	0.506
	Female	11	20.418		
VLM	Male	19	36.053	$-.924^{ns}$	0.363
	Female	11	31.818		
PLM	Male	19	36.227	-1.243^{ns}	0.225
	Female	11	26.97		

ns - not significant

Metacognition

Students' metacognition was also measured after each learning modalities using the SEMLI-S. Repeated measures ANOVA was used to analyzed scores taken before the start of classes, after MO, after VLM, and after PLM. First, epsilon (ε=.686) was calculated according to Greenhouse & Geisser (1959) due to violation of sphericity, this was used to correct the one-way repeated measures ANOVA. Results showed that at least one learning mode had significantly higher gain scores at $F(2.06, 59.72) = 9.67$, $p < .01$, partial $\eta^2 = .25$. Post-hoc analysis then follows using Bonferroni as suggested for datasets that violate sphericity in repeated measures ANOVA (Maxwell 1980), the result is presented in table 4. It was only in the fourth administration of the instrument where we observed improvement where PLM significantly increased metacognition from PreMO and MO classes. No other significant increase in metacognition was observed.

Table 5. Bonferroni post-hoc analysis of metacognition.

Distance Learning Modes (I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference Lower Bound	Upper Bound
PreMO	MO	-.124	.072	.585	-.328	.081
	VLM	-.410	.147	.055	-.827	.006
	PLM	-.621**	.137	.001	-1.009	-.232
MO	VLM	-.287	.140	.298	-.683	.110
	PLM	-.497**	.140	.008	-.895	-.099
VLM	PLM	-.210	.112	.417	-.526	.106

*Note: ** Significant at p<.01*

Sex and Metacognition

SEMLI-S scores across learning modes were also compared among sexes, the result is presented in table 4. Metacognition was statistically higher for males than females before classes start (PreMO) and after the end of classes that only made use of learning modules (MO) which is alarming as most schools in the Philippines only use modules during distance classes. However, at the third and fourth administration of the instrument, after two distance physics virtual laboratories and two distance physical laboratories, females have caught up – they now have statistically equal metacognition to males. (Yerdelen-Damar and Pesman 2013) had similar findings comparing physics metacognition between sexes. Though there were no treatments prior to the administration of the inventory, their measurement was conducted after the entire physics course. Thus, it is safe to assume that some laboratory experimentations were performed along the way that, like the current study, have improved female students' metacognition.

Table 6. Metacognition of male and female participants measured and compared after each learning modes.

Distance Learning Mode	Sex	N	Mean	SD	t	df	Sig. (2-tailed)
Pre-classes	Male	19	2.79	.20	2.412*	28	.023
	Female	11	2.49	.47			
PostMO	Male	19	3.02	.47	3.321**	28	.003
	Female	11	2.44	.44			
PostVLM	Male	19	3.24	.69	1.552	28	.132
	Female	11	2.83	.72			
PostPLM	Male	19	3.46	.58	1.765	28	.088
	Female	11	3.02	.79			

*Note: * significant at p<.05, **significant at p<.01*

DISCUSSIONS AND CONCLUSION

Learning physics has always been difficult and scary for many students (Lipszyc 2012; Williams 2000) due to traditional lectures and problem solving; thankfully, more and more modern teaching strategies are being discovered and implemented. In this study, we applied and tested in distance education some of existing and plausible pedagogies, these are module-only class (MO), distance virtual labs plus module (VLM), and distance physical lab plus module (PLM). All learning modules used were teacher-made that employs an inquiry-based approach while the laboratory activities were guided inquiry.

Results showed that all the three distance learning modalities have significantly higher posttest than pretest scores. Although all pedagogies exhibited learning effectiveness, it was with VLM that we observed a significantly higher gain score than MO which indicates that virtual labs successfully increased students' learnings from modules alone. Virtual labs have been observed to be more helpful in learning physics concepts compared to physical labs during F2F (Oymak and Ogan-Bekiroglu 2021) and even during distance classes (Bodegom, Jensen, and Sokoloff 2019) due to less efforts in setting-up of instruments and practically zero measurement errors. Some unnecessary and unintended learning likewise occurs in physical labs due to these errors. Lately, Dark (2021) and Nogueira and Hernandes (2021) demonstrated that both virtual and physical distance physics laboratory experimentations can possibly be conducted by students at home. In fact, Sithole et al. (2020) demonstrated that distance laboratories are not uncommon strategies to deliver physics instruction even before the COVID-19 pandemic. However, during the pandemic, the situation is worse due to lack of or slow communication between teachers and learners. Thus, physics teachers opted for computer simulations that proved effective in improving physics achievement during in-person classes (Bayrak 2008; Constante and Agsalud 2019) and during distance classes (Azizah et al. 2022; Onah et al. 2020; Yusuf and Widyaningsih 2020) similar to the findings of the current study.

Achievement scores between sexes were compared. Our study demonstrated that male and female students' gain scores were statistically equal across each learning modes. This finding is uncommon on physics achievement scores as several previous results showed that males outperformed their female counterparts in this specific area of science (Krakehl and Kelly 2021; Taasoobshirazi and Carr 2008). This cognitive difference among sexes though is caused by several factors such as interest in physics or even differences in abilities, e.g. girls are more inclined in reading (Stoet and Geary 2013) while boys have higher spatial ability (Voyer, Voyer, and Bryden 1995). Furthermore, due to increasing gender equality among communities, sex differences in physics achievement has also been diminishing in time (Miller and Halpern 2014). Philippines is one of those countries that succeeds in closing the gap between men and women (Schwab et al. 2019) thus supporting further the result of this study.

We also measured students' metacognition at the opening of school year (pre-MO), after MO, after VLM, and after PLM classes. We found that metacognition only improved at the fourth administration, after PLM classes, where results in the pre-MO and post-MO were significantly outscored. Improvisation of students' metacognition is helpful in learning physics (Anderson and Nashon 2007; McInerny et al. 2014) as this will make them inform, thus, regulate their own learning (Fouche 2013). Though metacognition may be improved through direct instruction, it may also be improved through exposure to some conditions that makes one aware and regulate learning such as writing of reflection (Langdon et al. 2019). In this study, it is shown that metacognition may also be improved through a conduct of physical physics lab similar to the findings of Sandi-Urena et al. (2012), an essential contribution to the field that lacks studies in improving metacognition (Zohar and Barzilai 2013).

When male and female students' metacognitions were compared after each learning modalities, males had significantly higher scores than females at pre-MO and post-MO partly explaining the differences in interests and abilities between these groups. However, these differences disappeared after VLM and PLM classes implying that female students caught up and had their metacognition improved after conducting labs.

Although VLM improved physics achievement scores better than PLM, it was only in PLM where we observed a significant improvement of metacognition which implies that, although physical labs did not significantly increase test scores from modular approach, it made the students become more aware and self-regulated in their learning. Like the findings from Puntambekar et al. (2021), this study had demonstrated again that physical and virtual labs are complementary and that they both must be used in physics instruction. Both physics labs also catered fairly to both sexes in terms of learning and metacognition, another reason not to hesitate from performing virtual or physical lab even during distance classes.

In this study, we were able to provide empirical evidence that conduct of both physical and virtual laboratory activities in physics are necessary even during distance classes as they improve physics achievement scores and metacognition. Adding to previous methods of improving metacognition, findings demonstrated that conduct of labs will also do the trick. Future studies may expound further on the impacts of conducting lab in students learning and abilities as well as explore on more methods to improve metacognition.

Given all this, the current study, like any other studies, have its limitations such as the small number of respondents and the highly criticized pretest-posttest research design. Due to our intent to be as less disruptive possible, we did not conduct interviews to gain insights on students' experience which could have given more substance to the study. This may also be considered by future research directions.

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REFERENCES

Adams, W. K., K. K. Perkins, N. S. Podolefsky, M. Dubson, N. D. Finkelstein, and C. E. Wieman. 2006. "New Instrument for Measuring Student Beliefs about Physics and Learning Physics: The Colorado Learning Attitudes about Science Survey." *Physical Review Special Topics - Physics Education Research* 2(1):010101. doi: 10.1103/PhysRevSTPER.2.010101.

American Association of Physics Teachers. 1998. "Goals of the Introductory Physics Laboratory." *American Journal of Physics* 66(6):483–85. doi: 10.1119/1.19042.

Anderson, David, and Samson Nashon. 2007. "Predators of Knowledge Construction: Interpreting Students' Metacognition in an Amusement Park Physics Program." *Science Education* 91(2):298–320. doi: 10.1002/sce.20176.

Azizah, Elza Varih, Asep Bayu Dani Nandiyanto, Tedi Kurniawan, and Muhammad Roil Bilad. 2022. "The Effectiveness of Using a Virtual Laboratory in Distance Learning on the Measurement Materials of the Natural Sciences of Physics for Junior High School Students." *ASEAN Journal of Science and Engineering Education* 2(3):207–14. doi: 10.17509/ajsee.v2i3.38599.

Bandura, Albert. 1977. "Self-Efficacy: Toward a Unifying Theory of Behavioral Change." *Psychological Review* 84(2):191–215. doi: 10.1037/0033-295X.84.2.191.

Bayrak, Celal. 2008. "Effects of Computer Simulations Programs On University Students' Achievments In Physics." *Turkish Online Journal of Distance Education* 9(4):53–62.

Bernard, Robert M., Philip C. Abrami, Eugene Borokhovski, C. Anne Wade, Rana M. Tamim, Michael A. Surkes, and Edward Clement Bethel. 2009. "A Meta-Analysis of Three Types of Interaction Treatments in Distance Education." *Review of Educational Research* 79(3):1243–89. doi: 10.3102/0034654309333844.

Bodegom, Erik, Erik Jensen, and David Sokoloff. 2019. "Adapting 'RealTime Physics' for Distance Learning with the IOLab." *Physics Teacher* 57(6):382–86. doi: 10.1119/1.5124277.

Carpendale, Jared, and Rebecca Cooper. 2021. "Conceptual Understanding Procedure to Elicit Metacognition with Pre-Service Physics Teachers." *Physics Education* 56(2). doi: 10.1088/1361-6552/abc8fd.

Collado, R. C. 2019. "Reducing the Gender Gap in Spatial Skills in High School Physics." *Journal of Physics: Conference Series* 1286(1):012013. doi: 10.1088/1742-6596/1286/1/012013.

Constante, Rhodel D., and Priscilla L. Agsalud. 2019. "Interactive Computer - Simulation Strategy and Physics Performance of Grade 8 Students." *ASEAN Multidisciplinary Research Journal* 2.

Cropley, Arthur J., and Thomas N. Kahl. 1983. "Distance Education and Distance Learning: Some Psychological Considerations." *Distance Education* 4(1):27–39. doi: 10.1080/0158791830040102.

Dark, Marta L. 2021. "Teaching an Introductory Optics Lab Course Online." *Physics Education* 56(5):055015. doi: 10.1088/1361-6552/ac080c.

Dastidar, S. G. 2021. "The Impact of Students' Perceptions of Online Learning Environments on Students' Satisfaction in the Context of Covid-19 Pandemic | Studies in Learning and Teaching." *Studies in Learning and Teaching* 2(3):61–72. doi: https://doi.org/10.46627/silet.v2i3.84.

DepEd. 2012. "Maximizing Utilization of National Achievement Test (NAT) Results to Raise the Achievement Levels in Low Performing Schools."

DepEd. 2020. "Official Statement on LESF | Department of Education." Retrieved May 24, 2022 (https://www.deped.gov.ph/2020/07/30/official-statement-on-lesf/).

Encarnacion, Riah F. Elcullada, Annjeannette Alain D. Galang, and Byron Joseph A. Hallar. 2021. "The Impact and Effectiveness of E-Learning on Teaching and Learning." *International Journal of Computing Sciences Research* 5(1):393–97. doi: doi: 10.25147/ijcsr.2017.001.1.47.

Espinosa, Tobias, Kelly Miller, Ives Araujo, and Eric Mazur. 2019. "Reducing the Gender Gap in Students' Physics Self-Efficacy in a Team- and Project-Based Introductory Physics Class." *Physical Review Physics Education Research* 15(1). doi: 10.1103/PhysRevPhysEducRes.15.010132.

Fouche, Jaunine. 2013. *The Effect of Self-Regulatory and Metacognitive Strategy Instruction on Impoverished Students' Assessment Achievement in Physics*. ProQuest LLC.

Fox, Michael F. J., Jessica R. Hoehn, Alexandra Werth, and H. J. Lewandowski. 2021. "Lab Instruction during the COVID-19 Pandemic: Effects on Student Views about Experimental Physics in Comparison with Previous Years." *Physical Review Physics Education Research* 17(1). doi: 10.1103/PhysRevPhysEducRes.17.010148.

Gambari, A. I., O. C. Falode, P. O. Fagbemi, and B. Idris. 2013. "Efficacy of Virtual Laboratory on the Achievement and Attitude of Secondary School Students in Physics Practical."

Greenhouse, Samuel W., and Seymour Geisser. 1959. "On Methods in the Analysis of Profile Data." *Psychometrika* 24(2):95–112. doi: 10.1007/BF02289823.

Guri-Rosenblit, Sarah, and Begona Gros. 2011. "E-Learning: Confusing Terminology, Research Gaps and Inherent Challenges." *International Journal of E-Learning & Distance Education / Revue Internationale Du e-Learning et La Formation à Distance* 25(1).

Haeruddin, Zuhdan Kun Prasetyo, Supahar, Elisa Sesa, and Gazali Lembah. 2020. "Psychometric and Structural Evaluation of the Physics Metacognition Inventory Instrument." *European Journal of Educational Research* 9(1):215–25.

Halpern, Diane F. 2014. *Sex Differences in Cognitive Abilities: 3rd Edition*. 3rd ed. New York: Psychology Press.

Hamed, Ghadeer, and Ahmad Aljanazrah. 2020. "The Effectiveness of Using Virtual Experiments on Students' Learning in the General Physics Lab." *Journal of Information Technology Education: Research* 19:977–96. doi: 10.28945/4668.

Heradio, Ruben, Luis de la Torre, and Sebastian Dormido. 2016. "Virtual and Remote Labs in Control Education: A Survey." *Annual Reviews in Control* 42:1–10. doi: 10.1016/j.arcontrol.2016.08.001.

Hoffmann, L. 2002. "Promoting Girls' Interest and Achievement in Physics Classes for Beginners." *Learning and Instruction* 12(4):447–65. doi: 10.1016/S0959-4752(01)00010-X.

Holmberg, Borje. 1989. *The Concepts and Applications of Distance Education and Open Learning*.

Holmberg, Borje. 2005. *Theory and Practice of Distance Education*. First edition. Routledge.

Iancu, Ana Maria, Kimberly Blom, Melissa Tai, and KitShan Lee. 2021. "Assessing the Effect of E-Learning on Perineal Repair Knowledge and Skill Acquisition: A Pre/Post-Intervention Study." *Journal of Obstetrics and Gynaecology Canada* 43(5):655. doi: 10.1016/j.jogc.2021.02.021.

Jones, M. Gail, Tammy Lee, Sarah Carrier, Lauren Madden, Emily Cayton, Katherine Chesnutt, Megan Ennes, Pamela Huff, and Lanette Phillips. 2021. "White Lab Coats and Elementary Students' Science Self-Concept and Science Self-Efficacy." *Science Educator* 28(1):1–9.

King, Frederick B., Michael F. Young, Kelly Drivere-Richmond, and P. G. Schrader. 2001. "Defining Distance Learning and Distance Education." *AACE Review (Formerly AACE Journal)* 9(1):1–14.

Kirk, Roger E. 2013. *Experimental Design: Procedures for the Behavioral Sciences, 4th Ed*. Thousand Oaks, CA, US: Sage Publications, Inc.

Krakehl, Robert, and Angela M. Kelly. 2021. "Intersectional Analysis of Advanced Placement Physics Participation and Performance by Gender and Ethnicity." *Physical Review Physics Education Research* 17(2):020105. doi: 10.1103/PhysRevPhysEducRes.17.020105.

Langdon, Jody, Diana T. Botnaru, Megan Wittenberg, Amy Jo Riggs, Jessica Mutchler, Matthew Syno, and Manuela C. Caciula. 2019. "Examining the Effects of Different Teaching Strategies on Metacognition and Academic Performance." *Advances in Physiology Education* 43(3):414–22. doi: 10.1152/advan.00013.2018.

Lipszyc, Carol. 2012. "A Fear of Physics: Interdisciplinary Learning in Grade Four." *Complicity: An International Journal of Complexity and Education* 9(2). doi: 10.29173/cmplct17992.

Long, Chong Yi, and Yeo Kee Jiar. 2014. "Mathematical Thinking and Physics Achievement of Secondary School Students." *Sains Humanika* 2(4). doi: 10.11113/sh.v2n4.492.

Lubinski, David, and Camilla Persson Benbow. 1992. "Gender Differences in Abilities and Preferences Among the Gifted: Implications for the Math-Science Pipeline." *Current Directions in Psychological Science* 1(2):61–66. doi: 10.1111/1467-8721.ep11509746.

Maligalig, Dalisay, and jose ramon Albert. 2008. "Measures for Assessing Basic Education in the Philippines." *Philippine Institute for Development Studies, Discussion Papers*.

Maxwell, Scott E. 1980. "Pairwise Multiple Comparisons in Repeated Measures Designs." *Journal of Educational Statistics* 5(3):269–87. doi: 10.3102/10769986005003269.

McInerny, Alistair, Andrew Boudreaux, Mila Kryjevskaia, and Sara Julin. 2014. "Promoting and Assessing Student Metacognition in Physics." *PERC 2014 Proceedings*. doi: 10.1119/perc.2014.pr.041.

Miller, David I., and Diane F. Halpern. 2014. "The New Science of Cognitive Sex Differences." *Trends in Cognitive Sciences* 18(1):37–45. doi: 10.1016/j.tics.2013.10.011.

Moosvi, Firas, Stefan Reinsberg, and Georg Rieger. 2019. "Can a Hands-On Physics Project Lab Be Delivered Effectively as a Distance Lab?" *International Review of Research in Open and Distributed Learning* 20(1). doi: 10.7202/1057970ar.

Morales-Menendez, Ruben, Ricardo A. Ramirez-Mendoza, and Antonio Jr. Vallejo Guevara. 2019. "Virtual/Remote Labs for Automation Teaching: A Cost Effective Approach." *IFAC-PapersOnLine* 52(9):266–71. doi: 10.1016/j.ifacol.2019.08.219.

Murphy, Patricia, and Elizabeth Whitelegg. 2006. "Girls in the Physics Classroom: A Review of the Research on the Participation of Girls in Physics." 67.

Nogueira, Giovana Trevisan, and Júlio Akashi Hernandes. 2021. "Laboratory Physics IV Based on Low-Cost Experiments: A Report on a Remote Teaching Experiencedue to the COVID-19 Pandemic." *Revista Brasileira de Ensino de Fisica* 43. doi: 10.1590/1806-9126-RBEF-2021-0242.

Onah, Eunice, Sunday Christian, Chinedu Okeke, Boniface Nworgu, Uche Agwagah, Chika Ugwuanyi, Pauline Obe, Mercy Nwoye, and Agnes Okeke. 2020. "Evaluation of the Impact of Computer-Assisted Instruction on Mathematics and Physics Students' Achievement: Implication for Industrial Technical Education." 13:1786–94.

Oymak, Onur, and Feral Ogan-Bekiroglu. 2021. "Comparison of Students' Learning and Attitudes in Physical versus Virtual Manipulatives Using Inquiry-Based Instruction." *IAFOR Journal of Education* 9(4):23–42.

Padios, Alfredo Jr. C., Rovelyn L. Lejano, Sophia Ann T. Gorospe, and Vanessa L. De Asis. 2021. "Strand and Statehood Predictors of Senior High School Graduates: A Tracer Study." *International Journal of Sciences: Basic and Applied Research (IJSBAR)* 55(1):211–24.

Puntambekar, Sadhana, Dana Gnesdilow, Catherine Dornfeld Tissenbaum, N. Hari Narayanan, and N. Sanjay Rebello. 2021. "Supporting Middle School Students' Science Talk: A Comparison of Physical and Virtual Labs." *Journal of Research in Science Teaching* 58(3):392–419. doi: 10.1002/tea.21664.

Pyatt, Kevin, and Rod Sims. 2012. "Virtual and Physical Experimentation in Inquiry-Based Science Labs: Attitudes, Performance and Access." *Journal of Science Education and Technology* 21(1):133–47. doi: 10.1007/s10956-011-9291-6.

Robertson, Kimberley Ferriman, Stijn Smeets, David Lubinski, and Camilla P. Benbow. 2010. "Beyond the Threshold Hypothesis: Even Among the Gifted and Top Math/Science Graduate Students, Cognitive Abilities, Vocational Interests, and Lifestyle Preferences Matter for Career Choice, Performance, and Persistence." *Current Directions in Psychological Science* 19(6):346–51. doi: 10.1177/0963721410391442.

Sagun, Richard Deanne, and Maricar Prudente. 2021. "Applying the Plan-Do-Study-Act (PDSA) Action Research Model to Re-Structure the Science Classroom Conforming to the Metacognitive Orientation Standards." *Educational Action Research* 0(0):1–17. doi: 10.1080/09650792.2021.1894964.

Salar, Riza, and Umit Turgut. 2021. "Effect of Differentiated Instruction and 5E Learning Cycle on Academic Achievement and Self-Efficacy of Students in Physics Lesson." *Science Education International* 32(1):4–13.

Salkind, Neil. 2010. *Encyclopedia of Research Design*. Vols. 1–10. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc.

Sandi-Urena, Santiago, Melanie Cooper, and Ron Stevens. 2012. "Effect of Cooperative Problem-Based Lab Instruction on Metacognition and Problem-Solving Skills." *Journal of Chemical Education* 89(6):700–706. doi: 10.1021/ed1011844.

Schwab, Klaus, Robert Crotti, Thierry Geiger, Vesselina Ratcheva, and World Economic Forum. 2019. *Global Gender Gap Report 2020 Insight Report.* Geneva: World Economic Forum.

Sithole, Alec, Edward T. Chiyaka, Fidelis Manyanga, and Davison M. Mupinga. 2020. "Emerging and Persistent Issues in the Delivery of Asynchronous Non-Traditional Undergraduate Physics Experiments." *International Journal of Physics & Chemistry Education* 12(1):1–7. doi: 10.51724/ijpce.v12i1.86.

Spector, J. Michael, M. David Merrill, Jan Elen, and M. J. Bishop, eds. 2014. *Handbook of Research on Educational Communications and Technology*. New York, NY: Springer New York.

Stoeckel, Marta R., and Gillian H. Roehrig. 2021. "Gender Differences in Classroom Experiences Impacting Self-Efficacy in an AP Physics 1 Classroom." *Physical Review Physics Education Research* 17(2). doi: 10.1103/PhysRevPhysEducRes.17.020102.

Stoet, Gijsbert, and David C. Geary. 2013. "Sex Differences in Mathematics and Reading Achievement Are Inversely Related: Within- and Across-Nation Assessment of 10 Years of PISA Data." *PLOS ONE* 8(3):e57988. doi: 10.1371/journal.pone.0057988.

Taasoobshirazi, Gita, and Martha Carr. 2008. "Gender Differences in Science: An Expertise Perspective." *Educational Psychology Review* 20(2):149–69. doi: 10.1007/s10648-007-9067-y.

Tan-lei, Daniel, and Xiaoqin Zhu. 2018. "Pretest–Posttest Designs." Pp. 1293–95 in *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation*. SAGE Publications, Inc.

Thomas, Gregory, David Anderson, and Samson Nashon. 2008. "Development of an Instrument Designed to Investigate Elements of Science Students' Metacognition, Self-Efficacy and Learning Processes: The SEMLI-S." *International Journal of Science Education* 30(13):1701–24. doi: 10.1080/09500690701482493.

Thomas, Gregory P., and Campbell J. McRobbie. 2001. "Using a Metaphor for Learning to Improve Students' Metacognition in the Chemistry Classroom." *Journal of Research in Science Teaching* 38(2):222–59. doi: 10.1002/1098-2736(200102)38:2<222::AID-TEA1004>3.0.CO;2-S.

Van De Heyde, Valentino, and Andre Siebrits. 2019. "Students' Attitudes towards Online Pre-Laboratory Exercises for a Physics Extended Curriculum Programme." *Research in Science & Technological Education* 37(2):168–92. doi: 10.1080/02635143.2018.1493448.

Viegas, Clara, Ana Pavani, Natercia Lima, Arcelina Marques, Isabel Pozzo, Elsa Dobboletta, Vanessa Atencia, Daniel Barreto, Felipe Calliari, Andre Fidalgo, Delberis Lima, Guilherme Temporao, and Gustavo Alves. 2018. "Impact of a Remote Lab on Teaching Practices and Student Learning." *Computers & Education* 126:201–16. doi: 10.1016/j.compedu.2018.07.012.

Voyer, D., S. Voyer, and M. P. Bryden. 1995. "Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis and Consideration of Critical Variables." *Psychological Bulletin* 117(2):250–70. doi: 10.1037/0033-2909.117.2.250.

Voyer, Daniel, and Susan D. Voyer. 2014. "Gender Differences in Scholastic Achievement: A Meta-Analysis." *Psychological Bulletin* 140(4):1174–1204. doi: 10.1037/a0036620.

Wan Ab Kadir, Wan Nurul Huda, Nurul Syafiqah Yap Abdullah, and Izan Roshawaty Mustapha. 2021. "The Effectiveness of Form Four STEM-Based Physics Interactive Laboratory (I-Lab) by Employing Isman Instructional Design Model." *Turkish Online Journal of Educational Technology - TOJET* 20(2):140–45.

Wang, Jingying, Donghui Guo, and Min Jou. 2015. "A Study on the Effects of Model-Based Inquiry Pedagogy on Students' Inquiry Skills in a Virtual Physics Lab." *Computers in Human Behavior* 49:658–69. doi: 10.1016/j.chb.2015.01.043.

Wen, Cai-Ting, Chen-Chung Liu, Hsin-Yi Chang, Chia-Jung Chang, Ming-Hua Chang, Shih-Hsun Fan Chiang, Chih-Wei Yang, and Fu-Kwun Hwang. 2020. "Students' Guided Inquiry with Simulation and Its Relation to School Science Achievement and Scientific Literacy." *Computers & Education* 149:103830. doi: 10.1016/j.compedu.2020.103830.

Williams, Karen. 2000. "Understanding, Communication Anxiety, and Gender in Physics: Taking the Fear Out of Physics Learning." *Journal of College Science Teaching* 30(4):232–37.

Xu, Hengwei, Siru Li, Wenpeng Song, Jiajun Sun, Xinli Wu, Xiaoqi Wang, Wenzhen Yang, and Zhigeng Pan. 2020. "Thermal Perception Method of Virtual Chemistry Experiments." *Virtual Reality & Intelligent Hardware* 2(4):305–15. doi: 10.1016/j.vrih.2020.07.003.

Yerdelen-Damar, Sevda, and Haki Pesman. 2013. "Relations of Gender and Socioeconomic Status to Physics Through Metacognition and Self-Efficacy." *The Journal of Educational Research* 106(4):280–89. doi: 10.1080/00220671.2012.692729.

Yusuf, Irfan, and Sri Wahyu Widyaningsih. 2020. "Implementing E-Learning-Based Virtual Laboratory Media to Students' Metacognitive Skills." *International Journal of Emerging Technologies in Learning (IJET)* 15(05):63–74. doi: 10.3991/ijet.v15i05.12029.

Zacharia, Zacharias C., and Georgios Olympiou. 2011. "Physical versus Virtual Manipulative Experimentation in Physics Learning." *Learning and Instruction* 21(3):317–31. doi: 10.1016/j.learninstruc.2010.03.001.

Zohar, Anat, and Sarit Barzilai. 2013. "A Review of Research on Metacognition in Science Education: Current and Future Directions." *Studies in Science Education* 49(2):121–69. doi: 10.1080/03057267.2013.847261.