



THE OPPORTUNITIES AND CHALLENGES OF INTEGRATING HOLOGRAM EXPERIMENTS INTO A HIGHLY VISUAL TELEPRESENCE COURSE

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ABSTRACT

Higher education is used to nurture advanced specialized training; however, nurturing innovative and practical ability is hard to put into practice. In experimental teaching, hands-on activities are offered to promote students' practical ability, leading to better-specialized training. This study aims to explore students' engagement, communication and collaborative skills, as well as learning outcomes by integrating hologram experiments into a university course. Eight university students participated in this study for 3-weeks. Hologram theory was taught in the first week, while in the second and third weeks, the students performed experiments. Pre- and post-test data were collected using questionnaires during the first and last week, respectively. Besides, in-depth interviews were conducted. The findings revealed that students were able to interact with each other, which promoted their engagement in experimenting. Moreover, teammates were able to communicate and collaborate effectively, which led to higher achievement in their learning outcomes. Despite the benefits reported, opportunities and challenges were identified for teachers and students to be aware of during hologram experiments to help them develop creative skills and develop an understanding of holography concepts.

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Keywords: integrated Hologram experiment; student engagement; communication and collaborative skills

INTRODUCTION

Higher education is used to nurture advanced specialized training with creative thinking and practical ability. How to develop a constructive education system that can develop innovative education and nurture talent has become an essential mission of higher education institutions (Yi et al., 2015). Nonetheless, nurturing innovative and practical ability is easy to promote but hard to put into practice (Yi et al., 2015). In science-based courses such as those for electronic and electrical information, optics and electrical engineering, practical teaching is a paramount ap-

proach (Guo & Rao, 2009). One of the practical teaching methods is experimental teaching; it can increase students' innovative and hands-on ability for a better learning outcome (Yi et al., 2015). By performing experiments, students are trained to solve practical problems through comprehensive practical ability (Guo & Rao, 2009). Experimental teaching can be defined as a process that includes a procedure carried out to support laid down assumptions. The procedures entail hands-on activities that engage and motivate students to learn in the science classroom (Doherty, 2011; Safaruddin et al., 2020). Zhang and Chen (2012) mentioned that experimental teaching helps students to build up creativity and hands-on activities to

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develop good groundwork for their future experimental work and study. Whereas in traditional teaching, only charts and writing boards are used to help students understand and master the related knowledge (Al-Qirim et al., 2017). It fails to effectively express difficult concepts and does not allow students to have a deeper understanding of abstract content (Zhang & Chen, 2012). However, with the development of the internet and technology, teachers can integrate optical components into their experimental teaching. This will avoid problems associated with the traditional teaching process, such as the inability to visualize abstract and difficult-to-comprehend concepts (Sutarto et al., 2018). Besides, new technology integrated with experimental practices will assist students to link abstract theories with real-life practical experiences.

Boelens et al. (2018) used blended learning design in higher education which provided students with additional support in product development but could not provide personalized instruction to students because it lacked strategies for differentiating special needs existing between students. Lee et al. (2017) applied flipped learning also in higher education. Their strategy showed a significant increase in students satisfaction and quality of concept reflections. However, it was difficult to generalize their result because the study was based on Algebra but not to other disciplines. Moreover, Vlachopoulos and Makri (2017) used games and simulation on higher education, which revealed that games and simulations motivate, engage and promote effective learning goals. However, the process of designing and simulations were costly and offered many challenges. It can be established that many strategies have been implemented to achieve better learning outcomes, but they have failed to either engage, support collaboration, or achieve significant learning outcome in higher learning. Therefore, for these reasons, the current study implemented experimental teaching in a higher education course called Highly Visual Telepresence and Display, which is a first-year master degree course. The study integrates both class lectures and experimental activity by allowing students to access learning materials a few days before the class and also engaging students in designing experiments.

Further, the experiments were carried in a well-equipped darkroom laboratory where each student performed their experiment. The results of this study will inspire teachers and students in designing learning and experimental activities which engages students, enhance communication and collaboration teamwork skills, to achieve bet-

ter learning outcomes since they will be aware of the opportunities and challenges experienced in the hologram experiment.

The commonly used method of instruction in higher education is lecturing (Tanel, 2008). However, researchers have warned that this conventional lecturing method hardly improves the teaching of principle concepts of physics in university-level courses. Even if lecturers make well-prepared presentations, they do not produce effective results in terms of understanding principle concepts (Tanel, 2008). Therefore, this study introduces a blend of lecture and experimental approach to enhance students engagement, communication and collaboration skills in learning of holography. All three variables are discussed below.

One way to improve the effectiveness of the lecture method is to introduce student participation through social interaction and collaboration (Tanel, 2008). This introduces activities that make students think about what they are doing and the applications they are carrying out. Besides, they can reflect on their ideas and prepare an environment which gives them a chance to discuss their learning with other students (Sağlam & Millar, 2006; Zhang & Cui, 2018). Although students are assessed individually in the classroom, group activities support the success of both individuals and the group (Khalil & Ebner, 2017). More often, students' success relies on communication and collaborative learning skills when sharing ideas in group discussions and experiments (Khalil & Ebner, 2017).

Further, Wang (2008) reported that by communication, group activities have the potential to offer real-time collaboration for one-to-one communication, immediate response and feedback, allowing the use of body language and gestures, and the use of tone variation. Khalil and Ebner (2017) defined collaborative learning as a pedagogy in which people come together in groups and learn from each other through cooperation. Within the group, each student takes responsibility for their learning and group by helping each other to be successful. Lee (2013) reported that the use of holography was an integral part of learning because it facilitated collaboration among learners and the construction of cognitive and social knowledge. Leonard and Fitzgerald (2018) found the use of holography supported collaboration and learning among students. Furthermore, Khalil and Ebner (2017) pointed out that during communication and collaborative learning, learners perform activities such as asking questions, providing explanations, and interacting with ot-

hers, which in turn triggers their learning. This will generate both cognitive learning outcomes as well as social competency, thus leading to better learning outcomes.

Therefore, to ascertain whether communication and collaborative skills could be supported during holography experiment, this study administered a communication and collaborative skills questionnaire and carried out interviews with the students.

Student engagement is defined as a range of actions students take to advance from not knowing, not understanding, not having skills, and not achieving to knowing, understanding, having skills, and achieving (Reeve, 2013). Student engagement is one of the critical competencies for individuals to interact in the 21st century (Reeve, 2013). Teaching/learning processes that do not engage students are deemed to be ineffective and register poor learning outcomes (Lin et al., 2018). Engaging students in the learning process will not only increase their attention and focus, but also motivate them to practise higher-level thinking and promote creativity and meaningful learning experience (Hadibarata & Rubiyatno, 2019). According to Reeve and Tseng (2011), there are four aspects of student engagement: behavioral, emotional, cognitive and agentic engagement, which are necessary for the learning process.

Similarly, a study by Lin et al. (2018) on engagement in learning found that a “just do in learning” project significantly facilitated students’ cognitive and affective engagement in the learning process during a fun camp, resulting in better learning outcomes. Leonard and Fitzgerald (2018) revealed that holography learning enhanced students engagement during the experiment which led to a higher learning outcome. Paredes and Vázquez (2020) mentioned that holographic teaching was an educational innovation tool that engages students. However, teachers experience play a crucial role in ensuring maximum benefit to students.

Therefore, to explore whether student engagement could be promoted in holography experiment, this study administered a student engagement questionnaire and carried out interviews.

Learning outcomes are measurable expectations a student is expected to know or do, or behavior to be demonstrated by a student after completion of a specific period of study. The expectations can be in the form of knowledge, skills or abilities acquired by a student by the end of the specified period (Bradford & Schnittman,

2013). According to Mahajan and Singh (2017), learning outcomes are indicators of the success of an academic course which gives a clear idea of what was achieved by the end of a particular process. Therefore, to measure the effectiveness of a learning process, learning outcome indicators are used, for instance by answering questions correctly, drawing accurate figures, writing essays, and so forth (Mahajan & Singh, 2017).

Moreover, Istrate and Miller (2009) reported that holography for 3D visualization allowed students to record their holograms. By doing this, students were able to register excellent motivation and learning outcomes, especially related to the interference, diffraction and coherence phenomena which showed a clear distinction between the science and art students. Paredes and Vázquez (2020) found that students who engaged with their teacher and teammates during holography experiment had better communication and collaborative skills, and registered better learning skills.

Therefore, to determine whether the experimental teaching method can result in better holography learning outcomes, this study administered a learning outcome questionnaire and carried out interviews with the participating students. Below are the research question of this study: (1) Does integrating hologram experimental activities affect students’ learning outcomes?; (2) Do hologram experimental activities engage and promote students’ communication and collaborative skills?

METHODS

This is a mixed-method experimental study conducted using one experimental group. The study was designed in two parts. The first week, the students were taught in class, while in the second and third weeks, the students performed the experiments. All the teaching materials, course outline, and lab schedule were posted in advance on Moodle for the students to prepare for the course.

In the first week, the students were taught theories in the fundamentals of optics, holography, and Michelson’s experiment. The mode of instruction included PowerPoint slides, inscribed videos, and a whiteboard to promote a highly interactive learning environment. During the class, the instructor and students interacted by asking and answering questions at any time. The first week’s session took 3-hours, with a break of 5-minutes after every hour.

All eight students who registered for the course participated in the study. They included two females and six male students. Seven of the participants were master's students while one was a PhD student.

This study was mixed-methods using both quantitative and qualitative methods. Pre- and post-tests were used to collect the participants' responses for the quantitative analysis, while researcher observation, participants' sit-in test and interviews were used as the data for the qualitative analysis.

This study took three weeks, with each week having its activities. During the first week, theories about fundamental of optics were taught in the classroom, including reflection, refraction, diffraction, interference, polarization holography, and Michelson's experiment. The mode of instruction included PowerPoint slides, inscribed videos, and a whiteboard. For the second week, their instructor began by showing a demonstration of how to generate a hologram from the computer, recording the hologram using optical component, and processing a hologram using Potassium Hydroxide. After the demonstration students performed hologram experiment in pairs by developing their hologram, each pair was given 30-minutes to record and develop their hologram. This session took 3-hours. During the third week, the teacher demonstrated the Michelson's experiment to all students. However, for this phenomenon, students were to set up the optical component by themselves until they visualize Michelson's experiment phenomenon.

Just like the second week, the third week took 3-hours with each pair given 30-minutes. For data, the first set of data collected was a pre-test during the first week. It was an online questionnaire sent to students via Moodle. The second data collection was done after the lab experiment in the third week. It was an online post-test questionnaire also posted on Moodle. Besides, a sit-in test was given to the students to evaluate their level of learning outcomes for the three weeks. Also, interviews were scheduled in the third week to gather more insights from learners about their experiences in the course. Four students were selected based on gender and how they participated in the course. These interviews were scheduled in an open environment conducive to the participants and quiet for audio recording. The interview took between 10 and 12 minutes each. It is essential to mention that no force whatsoever was applied to the interviewee to participate in the in-

terview. They were merely told about the criteria beforehand, and they willingly agreed to be interviewed. Furthermore, the researchers observed all the occurrences during the three weeks.

All of the participants were able to meet all of the requirements by attending all of the sessions, completing the questionnaires, taking the sit-in test and attending the interview session. To achieve data triangulation, the qualitative data from the students' responses were analyzed using content analysis (Angelova & Zhao, 2016). The data from the audio interviews were transcribed first before coding. Two independent researchers reviewed all the transcribed data and after that, generated codes to identify the participants' responses that represented the opportunities and challenges of this research. Their coding consistency was analyzed using inter-rater reliability, which found inter-rater reliability of 0.92 that was evaluated using Cohen's kappa. The differences that emerged between them after coding was further discussed in detail to reach an amicable solution. Shipe et al. (2013) highlighted that inter-rater reliability between 0.92 – 0.94 demonstrates a high consistency among individual raters. Therefore, this study reported high inter-rater reliability that meant the data analysis used was consistent.

Participant engagement was measured using a questionnaire adapted from Jamaludin and Osman (2014) and Elmaadaway (2018) with Cronbach's alpha of 0.79. All of the questions were multiple choice and were presented on a 5-point Likert scale, from *strongly disagree* (1 point) to *strongly agree* (5 points). An example item is, "I listen carefully to everything that is said in class." Besides, participants' communication and collaborative skills were measured using a questionnaire adapted from Lai and Hwang (2014) with Cronbach's alpha of 0.85 and 0.88, respectively. An example item is, "In class, I tried to make other students feel that they are important." All of the questions were multiple choice and were presented on a 5-point Likert scale, from *strongly disagree* (1 point) to *strongly agree* (5 points).

Furthermore, learning outcome was measured using a questionnaire adapted from Buechner et al. (2018) with Cronbach's alpha of 0.92. All of the questions were multiple choice and were presented on a 5-point Likert scale, from *strongly disagree* (1 point) to *strongly agree* (5 points). An example item is, "I am proud when I achieve better course understanding than before." Ong et al. (2020) highlighted that for Cronbach alpha above 0.62 it exceeds the minimum threshold for

a reliable scale. Therefore, since all the adopted scale exceeded the minimum reliability threshold, they were reliable and fit to measure each variable. In addition, a sit-in test was prepared for the students by two university instructors, one a professor for the course who had more than 15 years of teaching experience, while the other was a technician who had been carrying out similar lab experiments for more than 5 years. The researcher also recorded the daily class occurrences in the observation book that was used to report the students' activities during the class and lab sessions.

RESULTS AND DISCUSSION

This section is divided into three parts: quantitative analysis results, qualitative analysis results, and the researcher's observations, discussed in that order. Quantitative data was collected using questionnaires in pre- and post-test. The dependent variables measured from the pre- and post-test were the students' engagement, communication and collaborative skills, and their learning outcomes. The means and standard deviations for quantitative data were analyzed using *t*-test as shown in Table 1 to explore the effectiveness of the teaching method.

Table 1. The Means and Standard Deviations of the Dependent Variables

Item	Pre-test Mean	SD	Post-test Mean	SD
I listened carefully to everything said in class	4.13	.641	4.25	.463
In class, I asked questions about what I did not know	3.50	.535	3.88	.641
I interacted with my peers in class	3.63	.744	4.00	.535
I was alert in class	3.63	.518	3.75	.707
I preferred to complete assignments during class	3.75	.463	4.13	.641
I asked the teacher about difficult content	3.50	.535	3.63	.518
I attempted to apply things I learned during class	3.63	.518	3.75	.707
Being familiar with content prior to class motivated me	3.63	.518	4.00	.535
In previous courses, I strived to acquire new knowledge	3.50	.535	3.50	.756
Preparing for lessons enabled me to communicate better	3.50	.535	3.63	.916
I enjoyed this class	3.63	.518	4.13	.354
The teaching methods practised by the teacher were enjoyable	3.63	.518	4.13	.354
I enjoyed the activities conducted during class	3.63	.518	4.25	.463
I was optimistic about going to class with an understanding of the content	3.50	.535	3.88	.354
When I participated in class discussions, it boosted my confidence	3.63	.744	3.88	.354
When talking to my peers, I tried to make them have a good mood	3.75	.707	3.88	.354
I tried to make other students feel that they are important	3.38	.518	4.25	.463
I tried to communicate with others in a warm tone	3.63	.518	4.38	.518
When talking to others, I considered their feelings	3.50	.535	3.75	.886
I understood the privacy of what others had told me	3.50	.535	3.75	.463
I treated others with the same frankness as they treated me	3.63	.518	3.88	.354
In the teamwork, I believe the team members tried to complete their tasks	3.50	.535	3.88	.835
In the teamwork, our team successively collaborated to complete tasks	3.63	.518	3.88	.835
When my peers proposed ideas, I did not question their motives	3.13	.641	3.88	.991
When collaborating with peers, I communicated well with them	3.63	.518	4.00	.535
When collaborating with peers, each had tasks properly assigned	3.63	.518	3.75	.463
I was proud when I achieved a better course understanding than before	3.63	.744	4.13	.641
I was satisfied when I made progress in the course over time	3.25	.463	3.50	.756
I was delighted when I received better grades	4.00	.535	4.50	.535
I was fulfilled when I answered more questions correctly than before	3.63	.518	4.25	.463

The analysis of the pre- and post-test showed that the post-test means were higher than the pre-test means. The measured items in these questionnaires were related to how students behaved in class and the lab, how they participated in doing the experiments, and their learning process as a whole. Since all of the post-test means were higher than their respective pre-test means, this teaching method was considered to be effective in terms of engaging students and promoting their communication and collaborative skills. It can, therefore, be used to achieve a better learning outcome.

Analysis of the interviews with the students yielded three themes: students' engagement, communication and collaborative skills, and their learning outcomes. Student engagement was further identified as involving behavioral, emotional, and cognitive engagement. Communication and collaborative skills were identified as comprising teamwork benefits and teamwork challenges, whereas learning outcomes included a helpful learning method, need for improvement, and not helpful.

The students' responses showed that this teaching method engaged them in several ways. The engagement was categorized into three aspects: behavioral, emotional, and cognitive engagement.

This study had eight participants, some of whom had a physics background while others did not. It implied that the participants had different experiences in this study, therefore leading to different levels of engagement. This means that at some point they would adjust from their previous ways of learning and adapt to the current method used, for instance, working with new team members, doing experiments by themselves, and so on. One student stated that:

"The arrangement of the course is perfect. I can express that the first week I was a bit nervous because I did not know anyone in class; however, the teacher's activity made me feel comfortable, so I started participating in answering questions both in class and during the laboratory sessions" (S2_2).

This teaching methodology assisted students in improving on how they interacted with classmates and their teacher. For instance, one student mentioned that *"The class arrangement was ok; it assisted me to interact with my new friends and the teacher"* (S4_2). Another student mentioned that *"Since I am a beginner in this course and physics, the course structure assisted me with what to do, and when to do it"* (S1_2).

The students' comments indicate that they were able to perform the class and lab activities freely, were able to interact with their peers and instructor and enhanced their learning. Therefore, the teaching method was useful for promoting students' behavioral engagement and also for enhancing their learning outcomes.

The students' responses also showed that most of them asked questions, and they felt appreciative when the questions were well answered. Also, it solidified the sense of belonging in the class. Some student reactions include:

"During the class, I felt excited first because the teacher referred to me by my name. Secondly, I felt excited because of the holograms [pause] the teacher explained and answered the questions I asked about holography, and I was excited that I would see it in the lab" (S4_1).

Another student mentioned that although he had forgotten what he was taught in class, he asked similar questions while in the lab, *"I asked similar questions during the lab experiment although the teacher had introduced it in class. I asked again so that I could recall every component, and the teacher answered well"* (S2_5). Some students highlighted that they felt appreciative when the course was introduced from the fundamentals of physics, *"I felt like the course was designed for me; the teacher shared the history of optics, the classification of optics, and different ways of making digital holograms [pause] I felt happy"* (S1_1).

Responses from the students showed that the course and the teaching method used was suited to them because they felt appreciated, and it was like the class was meant for them. This was an indicator that this teaching method promoted the students' emotional engagement and could enhance their learning outcomes.

The students' responses revealed that they engaged with the content they were being taught not only during class time but also during the lab activities. This helped them to better their course understanding. One student highlighted that:

"The instructor content was more detailed than my previous classes/courses. It helped me understand the course. Also, it helped me understand the concepts I did not know at all, for example, reflection, refraction, diffraction, interference, scattering, and so on. I also asked my classmate who had a better background of physics than me about some other background of physics" (S1_1).

Another student highlighted that:

"The arrangement of the theory part [meaning the fundamentals of optics] is good. I can express that

the teacher taught from simple to complex, from concepts of physics. I now understand what I did not know –holography” (S2_2).

The strategies used to design the course helped the students to interact and engage easily with the content; for instance, they were able to follow what they were taught in class; further, they stated that the combination of class learning with lab activities enhanced their cognitive engagement. For instance, *“The teacher explained about holography in class, but I was anxious because I wanted to know what would happen in the lab” (S4_5).* There was a similar reaction to this by other students who mentioned that *“Before the experiment, I did not understand holography adequately; I was curious about how the image would be recorded” (S3_2).* Besides, S3 mentioned that: *“The interesting part was the computer-generated holograms, and how to input an image to become a hologram. When I was in class, it did not make sense, but during the lab experiment, I was able to understand it” (S3_3).*

These responses revealed that the students were able to interact with the content, whether in class or the lab. It also showed a high likelihood that this teaching method provided an environment for students to engage with the course content to enhance their learning cognitively.

Students’ responses showed that this teaching method promoted communication and collaborative skills in many ways. Communication and collaborative skills were categorized into two: teamwork benefits and teamwork challenges.

The following are some of the responses regarding teamwork benefits:

“I did discuss with my peer [peer means the teammate he/she paired with] especially when I did not see the output image [pause] this I asked my peer, but if the peer did not understand I asked the teacher” (S3_5).

Another student had a similar response to that of S3_5, which was:

“The most interesting part about the experiment was how to produce a hologram, and when I had a question I would ask my peer first then if he/she did not know the answer, I asked the teacher” (S4_4). The student further reported that: *“During the experiment, I interacted with both my peer and the teacher” (S4_5).*

Here the students supported the idea of communicating and collaborating with their teammates, that is the classmate with whom they were paired to experiment together. This was also recorded in the sentiments of S1_5: *“I had no problem interacting with my peer and also the teacher; if I*

had questions I asked my teacher, and I also had discussions with my peer. I can say the interaction was sufficient [pause] I mean there was sufficient interaction.”

Besides the students appreciated that they could ask questions, there was another aspect where students admitted that they needed a teammate, especially during the experiment:

“I can tell that the holography experiment needs more than one person to do it. For example, I needed a teammate to block the light for me so that I could put the holographic material in the right place, and to assist me with starting and stopping the stopwatch” (S1_5).

Apart from the response from S1_5, S2_5 also said that:

“I needed a teammate when I was washing the chemicals out of the holographic material. The teammate would also start the stopwatch to check the correct time needed to wash the material. I tell you, without that teammate, I would have forgotten to follow other steps like which part of the glass has the holographic material” (S2_5).

These responses indicated that the method of teaching for this course encouraged students to freely talk to one another, ask questions, either to their teammate or instructor, assist each other in experimenting, and be there for one another to remind themselves of all the required steps.

On the other hand, one student mentioned that, *“The two experiments were scheduled for two people to do together. I think I needed one more to do by myself so that I could gauge whether I understood the whole process or if I still missed some steps” (S3_5).* Although the experiment was designed for each member of the team to participate in, the lab was available for one more hour after the lab activities to allow a chance to learn for any student who wanted to learn more. This response was an eye-opener in this study; it raised two major concerns: (1) There is a need for proper strategies to be put in place when participating in teamwork; for instance, the responsibilities of each team member should be clearly stated; (2) There is a need for the creation of additional time to cater for special needs learners, for instance, slow-paced learners, inquisitive learners, and intrinsically motivated learners who wish to learn more for the sake of understanding. Furthermore, S2_6 complained that:

“My English proficiency level is not good. I had limited conversation with my teammate in English; however, I used Chinese because it is my first language to communicate with my Chinese teammate.”

The course was taught in English, so students who registered for the course were requi-

red to speak in English at all times; however, they were told the equivalent Chinese meaning of technical terms that they could not understand. The rest of the instruction was purely in English.

The students' responses showed that this teaching method promoted their learning outcomes in many ways. Learning outcomes were categorized into three aspects: a helpful learning method, need for improvement, and not helpful.

The following are some of the responses regarding the helpful learning method:

"I used the glass material [holographic material/film] and used the method the teacher showed me in the first example to input the image from the computer to the glass material" (S3_6). Here student S3 was trying to recall the steps for recording the hologram. After managing to record the hologram, he said: *"I felt a sense of accomplishment after recording the image on the holographic material by myself."*

Another response from S1_6 was: *"In the first experiment I followed the step-by-step instructions and recorded the hologram by myself, while for the second experiment [meaning the Michelson experiment] I saw the phenomenon of the experiment."*

S1 indicated that she was able to follow the steps for the first experiment until she was able to record the hologram. For the second experiment, she saw the phenomenon, meaning that she was the one holding the screen where the phenomenon was being displayed, while her teammate was the one adjusting the optical components on the table. The adjusted optical components included the lenses and the polarizers.

In addition to the above response, another student mentioned:

"I picked the image from the computer and placed it on the spatial light modulator. I also put the glass [holographic material] and put it on the correct position on the screen. My teammate started a stopwatch, which he stopped after 3 minutes. I removed the glass then washed it to remove the chemicals" (S2_6).

This student narrated the steps they followed in recording the hologram. In the narration, he talks about the procedure and some of the optical components that they used. It is evident that he was able to apply what he had been taught and thus showed that he had learned the concepts of how to print a hologram on holographic material. This was further supported by S4_6, who said, *"I put the glass in the right place, removed it after some time and washed it to clear the chemicals. I dried it using the hair drier. Finally, I had my hologram of the letter 'D'; I was happy."*

All the students were able to perform all of the necessary steps so that they could print the hologram. The instructor was in the lab all

the time to offer technical support. From the students' activities, it was evident that they had learned how to print a hologram. Therefore, this was a helpful learning method which can be used to promote better learning outcomes for students.

As the class and lab activities were going on, some students pointed out the challenges associated with the lab setup, for instance:

"The lab was too dark for me, bearing in mind that my background was not in physics. Secondly, during the experiment, the process was not easy, e.g. when kneeling on the floor, you need to be careful with the potassium hydroxide chemical" (S1_8).

This student mentioned the challenges she faced while in the lab. Some of them were new to her because she did not have any physics background. The other challenge was due to the nature of the experiment. Therefore, proper guidance needs to be put in place as early as possible so that students are aware of their expectations during the course.

S2_8 highlighted that:

"I felt uncomfortable because the lab room was small; it had narrow paths which interfered with my learning process." Like S1, student S2 had no background in physics.

Before going to the lab, the students were informed about the nature of the lab and given reasons why Holography and Michelson's experiment need to be performed in the darkroom. Some students seemed to be surprised because they had never seen a darkroom in real life and experimented in such an environment. However, all the students' faces were full of smiles when they saw the holograms that they had recorded by themselves. Although the process was full of challenges, the students' faces showed a sense of satisfaction when they saw their results.

This section explores students' responses regarding the reasons why the teaching method was not helpful. Some of the responses include:

"I was impressed most with how to produce a hologram. The other thing that I wish to mention is, the history part about the fundamentals of optics was too long. I expected more time and focused on Holography and Michelson's experiment" (S4_4).

Whereas S4 focused on the time and content of preference, student S3 reported that:

"During the class, the teacher used PowerPoint slides and a whiteboard. In the PowerPoint slides, the teacher only used short clips to emphasize ray tracing for optical paths, especially in experimental setups. I did not understand; however, if animations were used, it could be better for me" (S3_4).

Students S4 and S3 expressed what they saw as not helpful in the learning method. They

further gave suggestions as to what could be done to improve the teaching strategies so as to achieve a better learning outcome.

A few days before the class began, all of the teaching materials, including the course outline, course instructions, and PowerPoint slides were uploaded to Moodle. This allowed the students to interact with the course requirements as early as possible. The teaching method was a combination of PowerPoint slides embedded with short videos and a whiteboard for illustration, as shown in Figure 1.

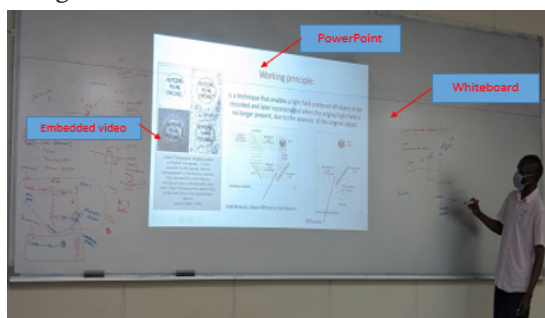


Figure 1. Illustration of Various Teaching Tools

During the first 10 minutes of the class, the instructor and students introduced themselves by mentioning their names and stating their majors. Most of them were seated in an upright posture, indicating either nervousness or a readiness to learn. However, the students' sitting position became more relaxed after the introduction. It seemed that after the students were given a chance to talk, their anxiety level decreased and they looked relaxed, primarily indicated by how they adjusted to a more relaxed sitting position.

The instructor began to teach as the students paid attention. The instructor called students by name to check whether they were understanding the concepts or not. The students were asked to state, for instance, the naturally occurring phenomena due to the behavior of light. Some students answered correctly, while others did not. When videos were played to demonstrate some of the naturally occurring phenomena, some students nodded their heads while some started talking to their friends in a low tone. Could it be that they were talking as a way of understanding? Maybe yes or no. This behavior of students nodding their heads and talking to nearby friends continued as the instructor switched from using PowerPoint slides, to the whiteboard, and to playing the embedded videos.

After 1 hour, the students took a 10-min break. Despite being given a break, most used

this time to ask questions about holography and Michelson's experiment at the whiteboard. At some point, they were saying, "Teacher, this is the most interesting part of this class," as shown in Figure 2.



Figure 2. Students Following a Discussion During Break Time

After the break, the teaching-learning method was similar to that of the first hour of the class. However, it was noted that the students became more active when the videos were played and when the teacher illustrated holograms and their applications. Later the students were talking in a low tone in class a discussion of the taught concept.

During the last minutes of the class, the students were reminded of the course expectations, the next meeting place, the kind of activities to be done, and the precautions to be followed.

The lab is where the experiments were done. The students were told about the nature of the lab and given reasons why the hologram printing needed a dark room, as shown in Figure 3 (a). Students were paired to assist one another in experimenting. The teacher demonstrated the experiment, and then it was time for the pairs to experiment by themselves. The pairs assisted one another in adjusting the optical components, suggesting ways to work through the challenging steps, using the stopwatch, and cleaning the holographic material.

Because each pair had two members, they had to repeat the experiment and compare the printed holograms. The most exciting part was the look on their faces after printing the hologram. "I felt excited, satisfied, I am happy, wow!" are some of the words they used to express their joy when achieving their learning goal. Figure 3 (b) shows one student holding a printed holographic film.

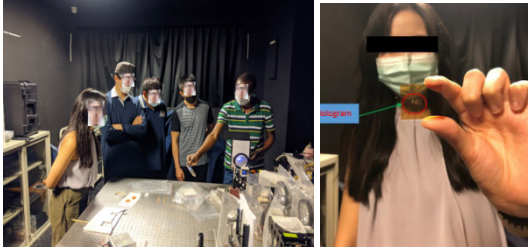


Figure 3. a) Teacher Demonstrates the Holography Experiment. (b) A Student Showing a Printed Hologram

During the third week, the students went back to the lab to perform Michelson's experiment. The experiment was first demonstrated, and then they carried it out by themselves. Just as in the holography experiment, they talked, assisted one another in adjusting the optical components, and recalled the essential steps in experimenting. Once they were able to visualize the phenomena, they did not hide their joy—they were so happy. One student who had no physics background was excited and said, “*I do not regret choosing this course; I have learnt a lot from it.*” Figure 4 shows a demonstration of the phenomenon of Michelson's experiment.



Figure 4. Teacher Demonstrates to Students Michelson's Experiment

The sit-in test had three questions, where each of the three subtopics had one question that tested the students' ability to remember, their understanding and their ability to apply (Agarwal, 2019). The taught concepts were the fundamentals of optics, holography, and Michelson's experiment. The three levels are based on Bloom's taxonomy which is essential for testing the learning process. The full score was 30 points. All of the students scored 28 or more points out of 30 points. This indicated that the teaching-learning method was effective in terms of achieving a better learning outcome.

This study explored an integrated teaching-learning curriculum that can be used to enhance students' learning and achieve better learning

outcomes during the COVID-19 pandemic. This section is divided into two: the quantitative and qualitative data analysis results, discussed in that order.

Research question 1: Does integrating hologram experimental activities affect students' learning outcomes?

The analysis of the pre- and post-tests showed that the post-test means were higher than the pre-test means. Measured items in this questionnaire were related to how the students behaved in the class and lab, how they participated in doing the experiments, and their learning process as a whole. The post-test of these items was higher than their respective pre-test, meaning that students effectively interacted, communicated, and performed better in the class and lab activities. Therefore, integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting students' interaction, communication and performance of the lab activities, which may have led to better learning outcomes. This answered the first research questions which asked whether integrating hologram experiments would enhance students learning outcome. This finding was consistent with Orcos and Magreñán (2018), who reported that the use of holography experiment in classroom motivated students to learn and thus promoted their learning outcome. Furthermore, Hoon and Shaharuddin (2019) explored the learning effectiveness using 3D holography; they highlighted that students gained holography knowledge and registered a better learning outcome.

Seemingly, although Li and Lefevre (2020) examined the use of holography in videoconferencing, their finding indicated enhanced teaching presence that engaged participants leading to a positive learning outcome.

To further understand how and why students' behavior changed during this period, a qualitative analysis was conducted. It involved content analysis of the student interviews and the researcher's observation of the sit-in test, as well as observations in the class and lab.

Research question 2a: Do hologram experimental activities engage students'?

During the content analysis, it was found that the students were able to perform class and lab activities freely, interacted with their peers and instructors, and followed instructions with minimal supervision. This showed that integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting students' behavioral engagement. Besides, the content analysis showed that, apart from

promoting students' behavioral engagement, the students felt appreciative when prompt feedback was given to them. Some felt that the course was specifically designed for them, and they were delighted. This indicated that integrating hologram experiments into the highly visual telepresence course was effective for promoting the students' emotional engagement.

Further, from the content analysis, the students expressed that before the course, they did not know what holography and Michelson's experiment were all about. Although they had learned about it in class, they could not imagine what it was. However, when they experimented themselves, they understood what it was. Besides, from their faces, it was clear that they were amazed about the result of the experiments and thus the learning outcome. This was an indicator that integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting the students' cognitive engagement. All three types of engagement, behavioral, emotional, and cognitive, formed the first theme for this study, students' engagement. Thus, integrating hologram experiments into the highly visual telepresence course was effective in terms of promoting students' engagement. This answered part of second research questions which asked whether integrating hologram experiments would engage students while learning. This analysis was consistent with Lasen et al. (2014), who suggested that students' engagement in science learning was enhanced when they were given an opportunity to have direct experience with science equipment while taking an active role, involving hands-on experimentation, and input into the experimental design. Moreover, Paredes and Vázquez (2019) reported that the use of a holography experiment enhanced campus students' engagement and enriched their learning experiences.

Research question 2b: Do hologram experimental activities support students' communication and collaborative skills?

Another theme that was revealed from the content analysis was communication and collaborative skills. This theme was measured in terms of teamwork benefits and teamwork challenges. During the learning process, the students communicated freely with their teacher and teammates. Although some students were nervous at the beginning of the class, they became free and courageous later on. Despite one student claiming that his level of proficiency in English was not good, he could still communicate with his teammate using their first language, which made them learn and understand. In addition, the students

admitted that they needed a teammate during the experiment so that they could collaborate on experimenting while also reminding themselves of the key points/steps so that they did not make mistakes along the way. Other than the teamwork benefits, the students faced challenges, especially while experimenting; for instance, some students felt that the time was not sufficient since they wanted to repeat the experiment several times because they were either slow learners or wanted to perfect and understand more. Despite the team challenges, they were able to communicate and improve their collaborative skills with their teammates as expected by their teacher. Thus, integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting their communication and collaborative skills. This answered part of second research questions which asked whether integrating hologram experiments would support students communication and collaborative skills. This outcome was consistent with Di Marco et al., (2009), who reported that university students in an applied optics course collaborated successfully in hologram experimental activities that fostered meaningful learning. However, it was demanding in terms of effort and time.

Furthermore, they emphasized the need for strategies to be put in place so that students can effectively achieve better learning outcomes. One possibility they suggested was to allow students to learn together in a dynamic process, but also the need to explain, share and possibly defend particular ideas within the group work. Likewise, Tayeh and Issa (2020) reported that the use of holograms was user friendly and a useful learning tool for students since it supported their collaborative skills.

Apart from revealing students' engagement and their communication and collaborative skills, the students' learning outcomes were revealed as another theme from the content analysis. Learning outcomes existed in the form of a helpful learning method, need for improvement, and not helpful.

As a helpful learning method, students narrated the processes of printing a hologram from having the holographic film, to showing their printed hologram. For Michelson's experiment, they also shared the steps from the beginning to the end, where they were supposed to see Michelson's phenomena. When the students were showing their final product, their faces were filled with joy and excitement, meaning that they were satisfied with what they had done. All students requested to carry their printed hologram,

possibly to show their friends or to have it as a memory for the future. Although the quality of the hologram was not tested, what mattered most was students were able to recall and understand the process of printing a hologram and displaying Michelson's phenomenon. Besides being a helpful learning tool, a few students suggested that the experiment process should be improved in terms of the physical lab environment; more space needs to be provided, precautions regarding the use of Potassium Hydroxide, and soft cushions provided because kneeling was not comfortable.

Further, one student mentioned that because he liked the holography part, he felt that the time spent learning other parts such as fundamental optics could be shortened. The teacher intervened by stating that the fundamentals of optics were crucial because not all students had a background in physics and so they needed it for better understanding. Despite these challenges, students were able to recall, understand, and perform the experiment as expected by their teacher. Therefore, integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting students' learning and better learning outcomes. This answered first research questions which asked whether integrating hologram experiments would affect students learning outcomes. This finding was consistent with Loveys and Riggs (2019), whose study examined the learning outcomes of second-year university students. They highlighted that laboratory activities helped students to: (1) bridge the gap between theory and practice; (2) enhance students' engagement with course material; and (3) significantly increase students' learning outcomes immediately after it was implemented in the curriculum. In addition, Orcos and Magreñán (2018) found that when the hologram was used in teaching, students got engaged and motivated to learn. On the contrary, Leonard and Fitzgerald (2018) highlighted that creative pedagogy design like hologram experiments sometimes is exceptionally challenging because of different cultural setup, and classroom/lab environment. Thus students might encounter challenges as they perform them.

To sum up, the researcher's observation converged with quantitative and qualitative analysis. These observations were made from the first to the last day of the teaching-learning process. It was noted that the students interacted with their teammates both in class and in the lab. This interaction encouraged them to engage in the course activities by working together, talking, performing experiments, and learning together. The interac-

tions revealed that the students' engagement with the course materials improved in their communication and collaborative activities which assisted them in achieving better learning outcomes. Besides this, the students' sit-in test also indicated that they were able to remember, understand and apply what they were taught as suggested in Bloom's taxonomy. Most of them scored 28 or more points out of 30 points. Thus, these findings answered all research questions. This was consistent with the study of Paredes and Vázquez (2019) who found that holography enhanced learning outcome on first-year engineering students. Therefore, integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting students' engagement, communication and collaborative skills, and achieve better learning outcomes.

CONCLUSION

This study integrated hologram experiment in a highly visual telepresence course offered as a fundamental course for students who wish to pursue physics-related careers. Findings revealed that the students were able to engage in fundamental of optics class and hologram experiment. Also, they were able to communicate and collaborate with their teammates while performing the hologram and Michelson's experiment. As a matter of working as a pair, they reminded themselves about the procedure and concepts of the experiment to ensure they followed the proper steps. In addition, the final sit-in test revealed that students were able to remember, understand and apply the concepts they had learnt, achieving a better learning outcome. This was based on the first three levels of Bloom's taxonomy. On the other hand, challenges were reported, especially about the processes involved in experimenting, the size of the lab, and the processes of experimenting. Despite these challenges, integrating hologram experiments in the highly visual telepresence course was effective in terms of promoting students' engagement, communication and collaborative skills, and achieving better learning outcomes. More so, there is a need to remind students of the course expectations every time to be aware of the expectations. This will ensure that the challenges stated earlier can be minimized to achieve the best possible learning outcomes.

The practical implications are as follows: (1) Prepare teachers and students whenever they intend to teach or take this course to be aware of opportunities and challenges they may experience and how to solve them; (2) Proper guidance

should be considered when pairing teammates and what each member is expected to do; this will avoid the need to create additional time for them to practice and understand the experiments. 3) The finding may inspire other teachers to implement them in teaching their practical subjects. The study was conducted with one course; therefore, findings can only be generalized for physics-related courses. A second limitation was the small sample ($n = 8$) although the findings were significant, they cannot be generalized to a larger population. Therefore, future studies could be conducted by increasing the scope and sample size for comparison and broad generalization.

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