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Home Experiment Program for Senior Mechanical Laboratory Course: A Laboratory Program during COVID-19 Pandemic

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Abstrak

Pandemi COVID-19 memicu perkembangan metode virtual dalam melakukan eksperimen untuk kelas laboratorium. Tetapi, metode virtual ini tidak dapat memberikan mahasiswa pengalaman praktikal yang seharusnya mereka dapatkan dari kelas laboratorium. Makalah ini bertujuan untuk mensosialisasikan program *Home Experiment* yang dilaksanakan oleh program studi Teknik Mesin Universitas Sampoerna. Program ini dibuat agar mahasiswa mendapatkan pengalaman pembelajaran praktikal selama pandemi dengan memungkinkan mereka melakukan eksperimen di rumah. Program ini diadakan melalui mata kuliah *Senior Mechanical Laboratory* (SML) dan hasil dari eksperimen yang berkaitan dengan perpindahan panas dibahas dalam makalah ini. Mahasiswa ditugaskan untuk merancang eksperimen yang berkaitan dengan heat transfer (dibimbing oleh dosen), membeli komponen yang dibutuhkan, merakit komponent, dan melakukan eksperimen. Selain menyerahkan laporan tertulis, mahasiswa juga diwajibkan mengirim video eksperimen dan mempresentasikan karyanya dalam sebuah konferensi di penghujung semester. Program ini diharapkan bisa menjadi studi kasus untuk pembelajaran berbasis rumah yang sangat penting selama pandemi berlangsung.
Kata Kunci: COVID-19; kelas laboratorium; praktikum di rumah; heat transfer; teknik mesin; pendidikan.

Abstract

COVID-19 pandemic triggers the development of virtual methods in doing the experiments for laboratory classes. However, the virtual methods cannot give the students the hands-on learning experience they should get from laboratory classes. This paper aims to disseminate the Home Experiment program conducted by the Mechanical Engineering study program of Sampoerna University. This program is established to allow students to conduct experiments at home so that they obtain a hands-on learning experience during the pandemic. The program is conducted through the Senior Mechanical Laboratory (SML) course, and the result of the heat transfer experiment is discussed in this paper. Students are assigned to design the heat transfer experiment (guided by the lecturer), purchase the required components, assemble the components, and conduct the experiment. Aside from submitting a written report, students are also required to submit experimentation videos and present their work at a conference at the end of the semester. It is hoped that this program will become a study case for home-based learning which is crucial during the pandemic situation.
Keywords: *COVID-19; laboratory classes; home experiment, heat transfer; mechanical engineering; education.*

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INTRODUCTION

The COVID-19 pandemic (Marinoni et al., 2020; Nashir & Laili, 2021; Ritchie et al., 2020) triggers various changes in education system all over the world, including Indonesia. On March 24, 2020, the Indonesian Ministry of Education and Culture issued Circular Letter No. 4 of 2020 concerning the Implementation of Educational Policies in the Emergency Period for the Spread of Coronavirus Disease (COVID-19) (*Mendikbud Terbitkan SE Tentang Pelaksanaan Pendidikan Dalam Masa Darurat Covid-19*, 2020). One of the policies in the circular letter stated that all educational institutions must be closed and implement online learning systems to minimize the spread of COVID-19. Following this policy, all universities in Indonesia must conduct all the classes online, including laboratory classes.

For some majors, regular and laboratory courses hold the same importance (Gamage et al., 2020). Through them, students can perform experiments to gain more hands-on learning experiences (Ackovska & Kirandziska, 2017). These experiments involve sensitive equipment, uncertainty on outcomes, and skills that students might apply for their future careers (Bretz, 2019; Kiely, 2021; Sansom & Walker, 2020). Students' engagement in laboratory courses also has better academic performance, social interaction, and research projects investment (Dominic & Hina, 2016; *Why Laboratory Courses Are Key to Career Success*, 2021; Wit et al., 2018). Laboratory classes are more into practical aspects. Thus, conducting laboratory classes online is more challenging compared to the regular classes. Also, the university needs to ensure that the students get the necessary skills and experiences without accessing the in-campus laboratories.

Zhai (Zhai et al., 2012) divides experiments during the online learning period into three forms: virtual, remote control, and video-based experiments. The virtual experiment uses simulation and virtual reality from technology. Usually, software or websites with open access anytime and anywhere is used if there is an internet connection. In electrical circuit experiments, for example, students can build their electrical circuits using Arduino (*Arduino Home Page*, n.d.). Another example is kinematic and dynamic analysis experiment by using GIM software (*GIM*, n.d.). Virtual experiments are user-friendly (Budai & Kuczmann, 2018), for example, if there is a mistake in connecting the circuit in virtual experiment, there will not be an explosion. Thus, students can be less worried. We note that these types of experiments will create no problems during the online learning period.

A study by Kapilan (Kapilan et al., 2020) shows the implementation of virtual laboratories in the mechanical engineering sector. The study concludes that virtual laboratory helps students increase their conceptual understanding. See for more studies on virtual laboratories in (Bahtiar et al., 2021; Nataro & Johnson, 2020; Vasiliadou, 2020). Similar to virtual experiments, remote control experiments are also accessible anytime and anywhere. The difference is that its setup is not virtual. It physically exists in the in-campus laboratory. A study by Andújar (Andújar et al., 2011) stated that the remote experiment improves student outcomes because it has a greater sense of realism. The video-based experiments allow the students to access the experiments' materials flexibly (anytime and anywhere). A study by Raida (Andújar et al., 2011) shows how a video-based experiment could be used in Physics class. The study states that the video-based experiments have good feasibility, making it worthy to be used as a medium of learning about optics in Physics class.

Even though the online experiment methods discussed above have advantages in helping the students, they lack hands-on experience. Thus, actual experimentation is still preferred during the online learning period to give the students hands-on experience. The key things here is that the experiments can be done at home. A study by Daren (Caruana et al., 2020), for example, shows how practical science can be done at home. Even though the components are not as fancy as those in the campus' library, this experiment gives the students hands-on learning experiences they should get. Another study conducted by Al Mufida and Widodo (Mufida & Widodo, 2021) shows that during the online learning period, irrespective of the media being used, a science concept cannot be understood by just theoretical explanations in the online class. Therefore, there is a need of a method such that the students can get hands-on experience while they are doing online learning.

Sampoerna University is an undergraduate educational institution based in Jakarta, Indonesia. As Jakarta is the city with the highest COVID-19 cases in Indonesia, Sampoerna University had to close since the beginning of the pandemic (*Data Pemantauan COVID-19 DKI Jakarta*, n.d.). Senior Mechanical Laboratory (SML) is one of the laboratory courses in Mechanical Engineering study program of Sampoerna University. Through this course, students can gain a deeper understanding of the theories they learned in regular classes, especially for thermodynamics, heat transfer, and fluid mechanics. Due to the pandemic situation in 2021, all classes including SML must be conducted online or must be done by online learning. To allow the students to get hands-on experience during online learning, the Home Experiment program is established for SML course. This paper aims to disseminate the Home Experiment program conducted at Mechanical Engineering study program of Sampoerna University.

The Home Experiment program allows the students to perform experiments and get more hands-on learning experiences from their homes. Instead of following an established experiment module, students are assigned to design their own experiment by following a rubric. By designing their own experiment, students can think of an experiment that they can do at home with available components in the market, and it is hoped that the students will be more knowledgeable. At the end of the program, the students disseminate their experiments' results in a conference so that they can learn from each other. Twenty-three students were taking the SML course during August – December 2021 semester. In the Home Experiment program, the students were divided into seven groups, and each group has three to four students. This paper will focus on the heat transfer experiments done by students under the Home Experiment program and how those experiments affect their skills and conceptual understanding of heat transfer phenomenon as mechanical engineering students.

To the best of the authors' knowledge, there is no literature discussing home-based experiments that can be used as a case study, especially in Indonesia. Therefore, this paper is expected to be the first literature for home-based experiments which will be useful for online learning during the pandemic period.

METHODOLOGY

This section explains the steps involved in the Home Experiment program: (i) students submit the proposal, (ii) students purchase the components, (iii) students assemble and perform the experiment, and (iv) students disseminate their experimentation results in a conference. Prior to the deadline of proposal submission (step (i)), the lecturer explains on the theoretical concept of heat transfer. The theoretical concept discussion is important so that students can get an idea of what they will expect from the experiment. The steps are shown in the flowchart of Figure 1.

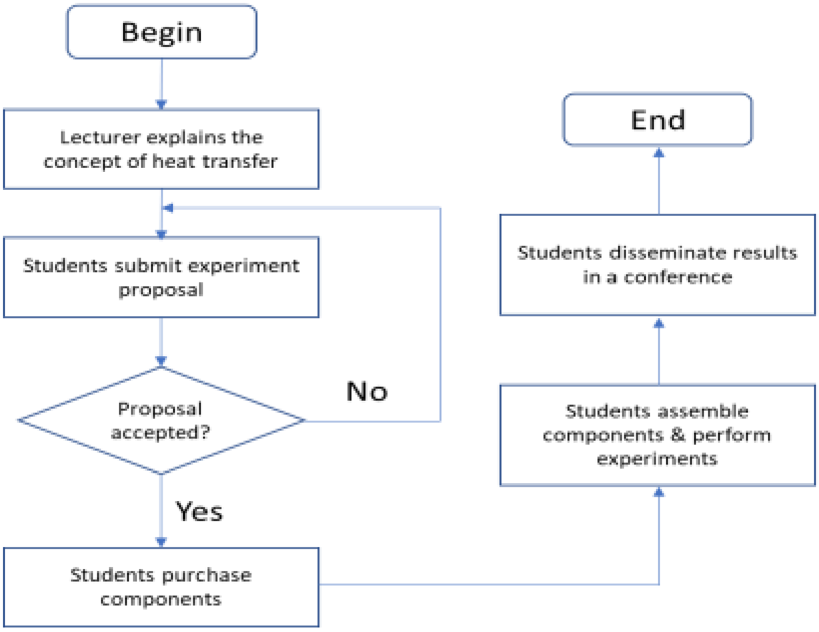

Figure 1. Flowchart of steps involved in home experiment program

Experiment's Plan Proposal

Every group must submit a proposal with one experiment covering a topic from Heat Transfer course. Before submitting the final experiment's plan proposal, students must submit the rough plan. Once the rough plan is approved, they can continue to make the proposal. The heat transfer experiments can only be approved if it allows the student to:

1. understand and apply the theory of heat transfer through experimentations,
2. analyze and evaluate the heat transfer performance and phenomena through experimentations,
3. implement data acquisition, data processing, and analyze experimental data, and
4. plan and build experimental setup related to heat transfer.

The approved topics for heat transfer experiments are tabulated in Table 1. As shown in Table 1, each group proposed different topics. The similarity is, they all observe the heat transfer phenomenon on their daily electronic devices, especially laptops and smartphones.

Table 1

The approved topics for heat transfer experiment in the Home Experiment program Fall 2021

Group	Topic(s)
1	Heat Transfer Phenomenon of Placing a Laptop on Hard and Soft Surface (Experiment 1)
2	Fan Cooler Effect on Phone's CPU Temperature (Experiment 2)
3	Steady State Time Measurement of Phone Temperature with Different Cooling Method (Experiment 3)
4	Effectiveness Comparison of Cooling Pad and Mini Fan to Reduce the Temperature of an Overheated Laptop (Experiment 4)
5	Analysis on the Effectiveness of Cooling Pad for Overheating Laptop (Experiment 5)
6	Heat Transfer Analysis of the Laptop's Temperature using Laptop's Fan Mode under Different Circumstances (Experiment 6)
7	Effect of External Fan to the Laptop's CPU Temperature (Experiment 7)

Experiment 1 focuses on how surface textures of the place where a laptop is placed affecting its temperature. This experiment uses two laptops (laptops H and L). The conduction heat transfer occurs between the surface and the laptop. It is calculated using Equation 1 (Bergman et al., 2017).

$$q = kA\frac{\Delta T}{L}, \quad (1)$$

where k is the thermal conductivity of the material (aluminum) in $\mathrm{W/mK}$, A is the cross-sectional area of the contacted surfaces in m^2, ΔT is the temperature change in K, L is the heatsink length in m. Experiment 2 allows the student to understand the working principle of a fan cooler and analyze its effect on CPU's temperature of a smartphone. In this experiment, the student will record the initial CPU temperature, loaded temperature, and cooling time on two scenarios: when the fan cooler is used and unused. Then, the student will compare the result to know whether the fan cooler has any effect in cooling down the CPU's temperature or not. In Experiment 3, the phone is used for several minutes to increase its temperature. Then, three cooling methods was adopted to measure the time needed for the phone to reach steady-state temperature (room temperature). At the end, the student will determine the rate of temperature change for each cooling method using Equation 2 (Bergman et al., 2017).

$$\frac{dT}{dt} = \frac{T_2 - T_1}{\Delta t} \quad (2)$$

Where, $\frac{dT}{dt}$ is the rate of temperature change in $\mathrm{C/s}$, T_1 and T_2 are the initial and final temperature of the phone, respectively, and Δt is the settling time. Experiment 4 is similar to Experiment 2, but it has additional cooling method, which is by using cooling pad. Experiment 4 compares the effectiveness of cooling pad and mini fan to cool an overheated laptop. Experiment 5 is similar to Experiment 4, but it focuses only on the effectiveness of cooling pad in reducing the temperature of an overheated temperature. While Experiments 2 to 5 use external cooling tools, Experiment 6 uses the fan mode feature within the laptop. The experiment is performed under the same circumstances as in Experiment 1. Experiment 7 is similar to Experiment 2. The only difference is the electronic device used in the experiment. While Experiment 2 uses a phone, Experiment 7 uses a laptop.

Purchase of Components

Once the group's proposal was approved, the students can start purchasing the components needed for their experiments by referring to the stipulated budget. The given budget was estimated using experiments that does not use fancy components but could cover the cost of the experiments that would be done by the students. Purchasing the required components by the students themselves gives a new experience and it makes the students to have a feeling of owning their own experiments.

Assembly and Experiment

The students assembled the components for their experiments according to the proposal they had made. Once the setup was ready, the students could perform their experiments. During this process, some students needed to go back to the previous stage to get a better result with respect to their hypotheses. To allow the lecturer to monitor the experiments, the assembly and experiment process were recorded. Figure 2 to 8 show the experimental setups of Experiments 1 to 7.

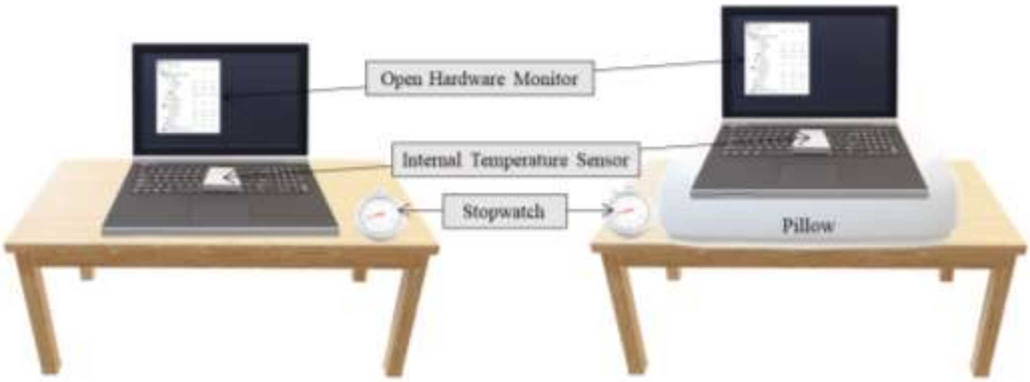

Figure 2. Experiment 1 setup

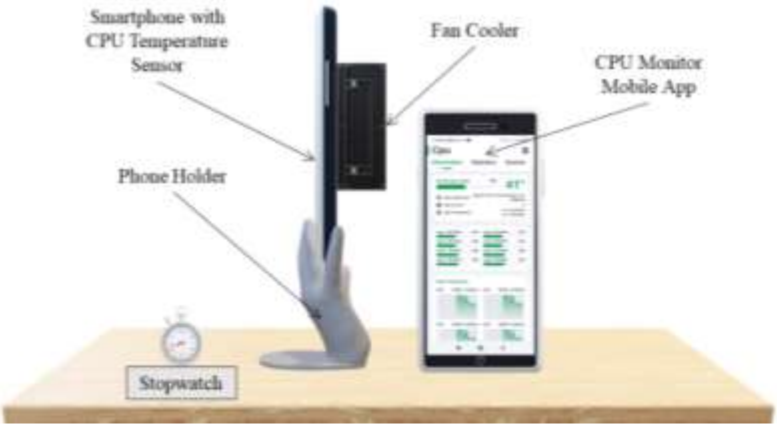

Figure 3. Setup for Experiment 2 and 3 (when the overheated phone is subjected to a fan cooler only)

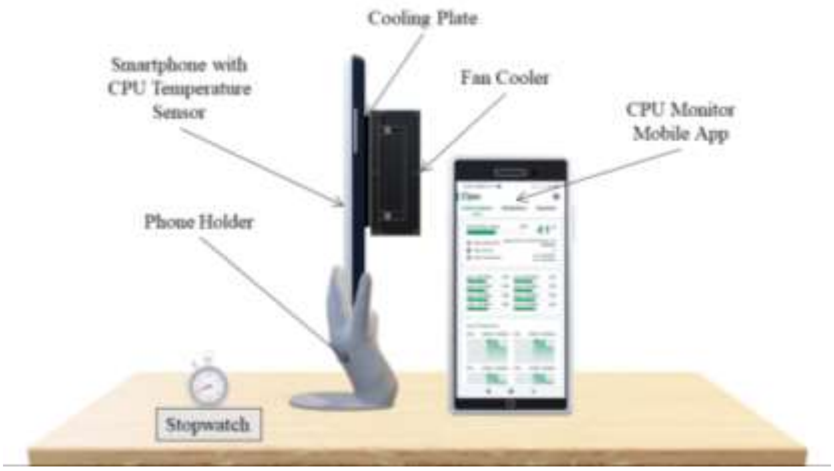

Figure 4. Experiment 3 setup when the overheated phone is subjected to a fan cooler and cooling plate

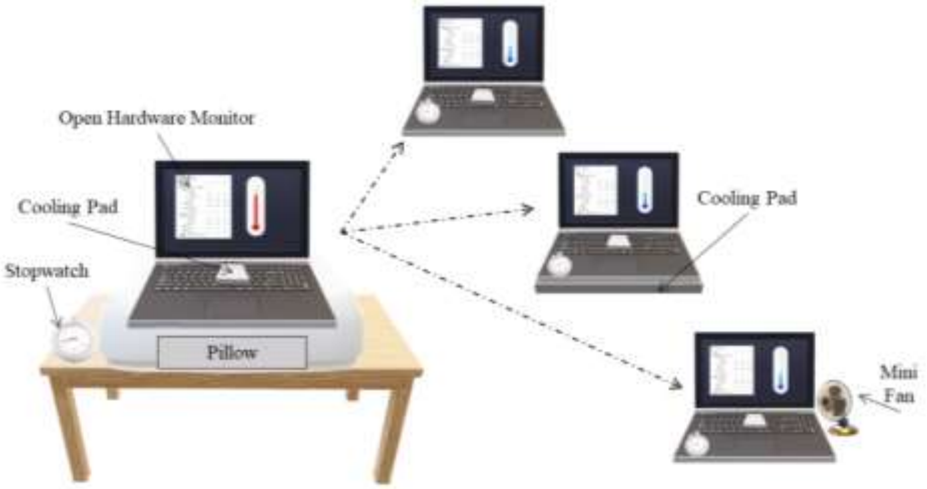

Figure 5. Experiment 4 setup

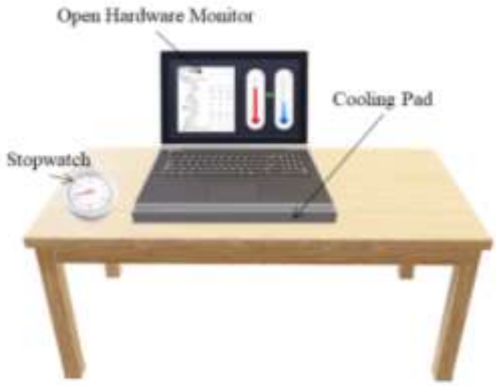

Figure 6. Experiment 5 setup

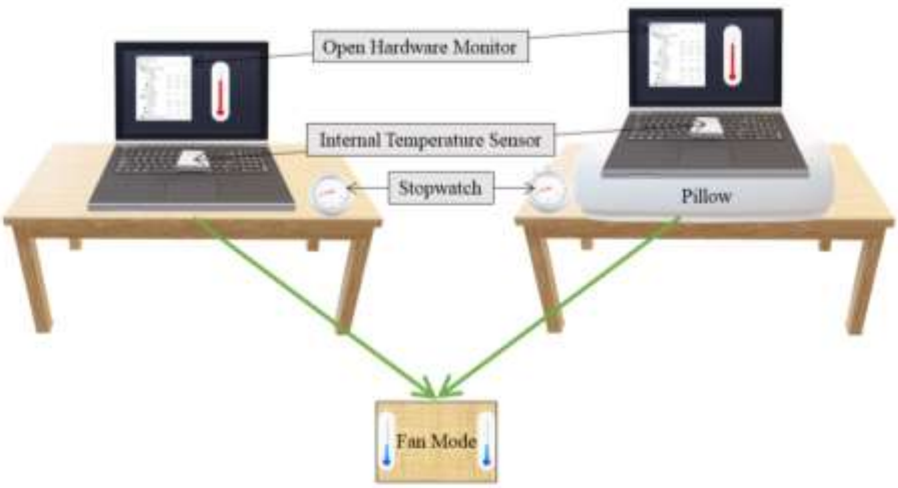

Figure 7. Experiment 6 setup

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Figure 8. Experiment 7 setup

Conference

In the last stage of the home experiment program, the conference was held once all groups finished their experiments as part of the learning process. The title of the conference is "2021 Senior Mechanical Laboratory Conference" with a theme of "Learning Heat Transfer, Fluid Mechanics, and Thermodynamics in the New Normal Era". In this conference, the students presented the findings and results from their experiments individually. Students give questions to their peers related to the findings from the experiments and they learned from each other.

RESULTS AND DISCUSSIONS

The Experiments

All the experiments in Table 1 were performed successfully. The recorded assembly and experimentation processes were uploaded on SML YouTube channel for Fall 2021 learning period, namely Mech 4226F21. Figures 9 – 15 show the screenshots taken from the YouTube channel Mech 4226F21 that show the students performing the home experiment of heat transfer.

Figure 9. Experiment 1 demonstration (Mech 4226F21, 2021)

Figure 10. Experiment 2 demonstration (Mech 4226F21, 2021)

Figure 11. Experiment 3 demonstration (Mech 4226F21, 2021)

Figure 12. Experiment 4 demonstration (Mech 4226F21, 2021)

Figure 13. Experiment 5 demonstration (Mech 4226F21, 2021)

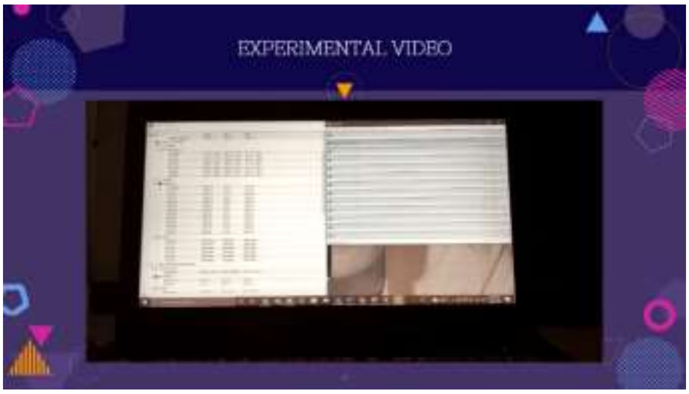

Figure 14. Experiment 6 demonstration (Mech 4226F21, 2021)

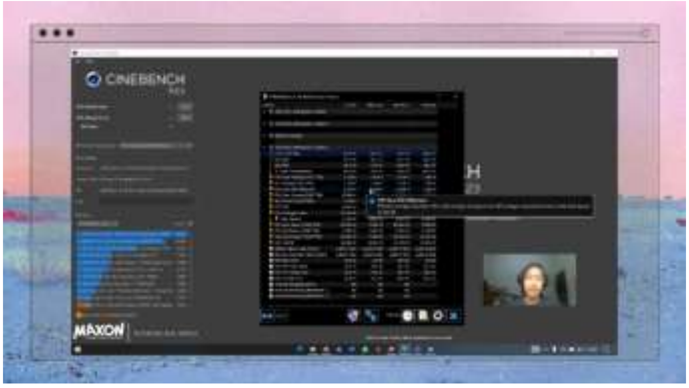

Figure 15. Experiment 7 demonstration (Mech 4226F21, 2021)

As shown in Figure 9 – 15, all the demonstration videos of Experiment 1 – 7 are uploaded on Mech 4226F21 YouTube channel. Through these videos, students can share the processes and the results of their experiments. They can also watch each other's experiments. The videos are available to the public. Thus, everyone can watch their experiment demonstrations. If there are other students doing the same experiment as one of the SML students, and they want to compare their results with them, they can use these videos as a reference since the SML students also show their experiment results. The results of the experiments are tabulated in Table 2.

Table 2
Results of the experiments on heat transfer for SML course.

Experiment	Result(s)
1	- For Laptop L: With initial temperature of $41°C$, the final temperature of the laptop when placed on a pillow (soft surface) is $8.5 - 10\%$ higher than when it is placed on a table (hard surface). - For Laptop H: With initial temperature of $46°C$, the final temperature of the laptop when placed on a pillow (soft surface) is $2.9 - 4.7\%$ higher than when it is placed on a table (hard surface).
2	- Under room temperature setting, the phone has an average cooling time of 3 minutes and 11 seconds. - By adding a fan cooler, the cooling time reduced to 1 minute and 29 seconds.
3	- Using cooler fan and cooling plate reduce the temperature of the phone faster with a cooling rate of -0.057 °C/s.
4	With initial and final temperature of $70°C$ and $50°C$, respectively, each schematic has the following average cooling time: - Without any device = 227.6 s - With a cooling pad = 116.4 s - With a mini fan: Low speed = 266 s High speed = 254 s
5	- Cooling pad helps reducing the temperature of an overheated laptop.
6	For the experiment on a pillow (hard surface): - Idle (Silent Fan Mode): no significant different. - Heavy load (Silent Fan Mode): the maximum package temperature ranged from $84 - 86°C$. - Heavy load (Balanced Fan Mode): the maximum package temperature ranged from $88 - 89°C$. - Heavy load (Overboost Fan Mode): the maximum package temperature ranged from $88 - 89°C$. For the experiment on a table (hard surface): - Idle (Silent Fan Mode): no significant different.

	- Heavy load (Silent Fan Mode), heavy load (Balanced Fan Mode, and heavy load (Overboost Fan Mode) have the same maximum package temperature range, which is $88-89°C$.
7	- The laptop's CPU temperature with a cooler fan beside is $5.96°C$ lower than operating it without the cooler fan.

From the results of Table 2, students figured out how different circumstances, cooling methods, and device specifications affect the cooling process of electronic devices. Electronic devices placed on a soft surface will have a faster temperature change and will have a higher final temperature compared to when they are placed on a hard surface. The cooling rate is also different. With the same cooling tools, electronic devices on a table will cool down quicker that when they are placed on a pillow. Additional cooling tools, such as fan and cooling plate, helps in speed up the cooling process of electronic devices. The specifications also affect their heat transfer rate. It is affected by the clock speed and installed RAM.

A follow-up interview was conducted to find out the effect of Home Experiment program on the students' skills and conceptual understanding on heat transfer even though they could not go to the laboratory. During the interview, all students agreed that Home Experiment program helps them in improving their experimentation skills, such as experiment planning, results validation, and setup making. They also learned other skills that can be useful for them as mechanical engineering students, such as creativity, critical thinking, and decision making. Home Experiment program also proves that experiments can be done not only in the laboratory but also at home.

The Conference

The conference was also successfully held. Students are able to present the results and findings from their experiments. Since some of the experiments are similar, the students can complete each other's results during this session. During the interview, the students also said that the conference increases their public speaking and presentation skills. The only flaw for this conference is the duration takes too long. It happened because all experiments were presented in one day. Staying in front of a laptop the whole day made them tired. They suggest that the next conference can be divided into two or more sessions to keep the productive atmosphere within the students.

Remark

From the Home Experiment program conducted in SML course, we found that students can perform the experimentation independently and they get the expected experimentation results. Students are given freedom to explore their understanding on heat transfer by designing their own experiments. As a result, we can see students' creativity in designing the experiment and we can clearly see their effort when conducting the experiment. When students are given freedom to explore their knowledge, we can really see their true potential. However, the disadvantage comes when the students themselves are not motivated. Thus, the lecturer must guide them and give clear checkpoints or deadlines so that students can perform the necessary steps without exceeding the deadlines.

CONCLUSIONS

A virtual laboratory can be a solution for conducting online laboratory classes during the COVID-19 pandemic. However, virtual laboratory does not give the students hands-on experience, which is one of the ultimate goals of a laboratory course. This study shows how letting the students perform semi – guided experiments at home can solve this problem.

Home Experiment is a laboratory program created by the Mechanical Engineering study program of Sampoerna University to allow students to conduct laboratory experiments at home during the COVID-19 pandemic. This program ensures that the students can get the hands-on experience as much as possible even though they cannot access the in-campus laboratory. Focusing on heat transfer, the students can get hands-on experience through experiments. They can implement their knowledge in the Heat Transfer course to analyze the heat transfer phenomenon in electronic devices, especially laptops and phones. They also gain laboratory and engineering skills, such as experiment planning, critical thinking, setup and decision making, result validation, and creativity during the process. Through the conference at the end of the program, they learned how to deliver the findings from their experiments. Moreover, according to students, it also increases their presentation and public speaking skills. In the end, the Home Experiment program is able to give the students both conceptual understanding and hands-on learning experiences through the heat transfer experiments and conference.

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