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Analysis of undergraduate students' learning experience regarding hands on laboratory courses using new innovated techniques of hybrid delivery

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Session XXXX

Analysis of undergraduate students' learning experience regarding hands on laboratory courses using new innovated techniques of hybrid delivery

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Abstract

Year 2020 witnessed a severe adverse effect of COVID-19 pandemic on the engineering and technology education, especially, where laboratory based hands-on activities are integral parts of the learning process. Due to the health risk and CDC guidelines, several universities all over the United States switched to online instructions, mostly relying on virtual lecture delivery tools and simulation software which substitute some lab-based activities. This research is oriented to offer and evaluate the effectiveness of some new methods for lab-based course instruction and assessment. Several courses offered in the Engineering Technology department at NSU, including Manufacturing Processes, Technical Drafting, Electrical Principals II and Digital Electronics II, require lab-based hands-on activities for strengthening theoretical knowledge. However, the face-to-face meeting with the students in these courses have been restricted due to the pandemic since March 2020. In this situation, we offered several innovative hands-on learning methods and assessment tools customizing respective course requirements. These methods include, (i) giving small individual project, (ii) distributing equipment to the student allowing work at home, (iii) using simulation software, and (iv) providing video instruction for the hands-on activity. The performance of the students is assessed by (v) oral presentation and oral examination, (vi) random quiz from large question bank, (vii) structured report writing, (viii) personalized lab test by random experimental setup, and (ix) video/picture/product submission from the completed hands-on activity. The effectiveness of these methods and tools is evaluated by a structured survey among the respective students, on a five-point Likert scale defined as, 5—Strongly agree, 4—Agree, 3—Neutral, 2—Disagree, and 1—Strongly disagree. Statistical analysis of the survey result supports the hypothesis that the students have more than just neutral (H_0: $\mu > 3$) feelings towards several new instruction methods and assessment tools in the four courses listed above. We, in the Engineering Technology department, are continuing our research with several other innovative ideas focused on improving student's learning experience in online and hybrid environment.

Introduction

During spring 2020, we had to adapt complete online teaching in both theory and laboratory courses

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in response to the growing COVID-19 pandemic. The faculty as well as students were not ready for such a transition from the class-based education to completely online education. The on-campus residents were advised to return home if possible. Help was promised to those who absolutely must stay on campus [1]. The whole idea was to contribute to flattening the transmission curve of the coronavirus. The key challenge was to figure out how to get up to the speed of teaching online. Initial lack of infrastructure and strategies were noticeable. Some earlier training in developing and teaching entire course online was not enough. We got one day training from the online service developers of the university on the virtual platform called 'WebEx' to deliver our lectures by sharing the contents of our laptop screens with those of the students. Within three weeks we improved well in terms of communicating with one another though the mental health of the students deteriorated because of stress and anxiety from pandemic and lockdown. But the real problem was that all the students did not have equal accesses to, and expertise on digital technologies [2].

Running Strategy for Online Labs

During spring 2020, EET 1321 Electrical Principal II laboratory course was taught by one of the authors. The students start performing the entire laboratory experiments by building circuits using discrete components on breadboards in EET 1321 AC circuits laboratory course until the middle of March 2020. Immediately after that they began assembling the circuits and collecting data on the laptop screens by using a simulation software called MultiSim 12. Initially it was a shock to them. But gradually they became used to the new life as their performance improved. As the students were unable to access the on-campus laboratory equipment of the department, the college of Business and Technology kept one of their computer labs equipped with MultiSim 12 simulation software for the students. The students were advised to install the software in their own computers if possible. The installation procedures were sent to them with links to some example videos. Our laboratory supervisor played a very useful role in helping the students. The students watched some power point presentation of working labs posted in the Moodle before doing actual lab at the prescribed time. The instructor continued providing prelab lecture what he was doing in face-to-face time. But he used the WebEx' platform. At this time, the instructor was overwhelmed by many challenges as the usual feedback loops were disrupted by remote teaching. All the students were not getting equal and desirable support from the instructor within the lab time. For the aid to the students, he appointed two students among the students who finished their lab assignments early. They received extra credits for helping other students to download the software in their computers, answering their questions, and helping them in troubleshooting their labs under the supervision of the instructor [3]. That was an innovative solution as it brought fruits for all the students in those classes.

In fall 2020, EET 3311 Digital Circuits II laboratory course was taught using 'HyFlex' method of delivery of course materials. In a HyFlex course, courses are delivered both in person and online at the same time by the same faculty member. Students can then choose for each class meeting whether to show up for class in person or to join it online. In NSU, the course was divided into two sections. The students in one section were coming to the class in person for half of the time whereas the other section members were getting instructions online. The instructor modified the delivery process to improve the learning of the students. It is at least in its original conception, designed for the students who live on or close to campus. It does not furnish full solution of distance education but only to

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provide the residential and commuter students the flexibility to attend classes in person or remotely. The effects of pandemic force the schools to decide how many students they can put into a classroom. The idea was to make the online and in person experiments equal by maintaining social distancing. Participation in the classroom was fulfilled either in terms of in-person or remote [4]. In the Northwestern State University, the whole class was divided into two sections. The class time was from 2:00 to 3:40 pm. The first section did the lab in person from 2:00 pm to 2:50 pm while the second section was in online setting. The second section then come to the class in person at 2:51 pm and finish the lab at 3:40 pm while the first section moves to online setting till 3:40 pm. The students could take home some components like breadboard, chips, and wires to build up part of the lab before coming to the lab in person to finish the lab. Very soon it was found out that the students were struggling to build up and collect data from circuits for one lab within the allocated time. As they were using discrete components and chips it was even harder. Some of the students were commuting for around thirty minutes which was a loss of valuable time. In most of the cases, they finished one lab in two weeks while one lab per week was the norm. At the same time, it was not easy to maintain social distancing as well as coordination.

In spring 2020, IET 4730 Manufacturing Processes course was taught. This is a four (4) contact hours course, out of which two (2) contact hours are allocated for lab experience and hands-on activities. The classes in spring 2020 started face-to-face, however in the middle of the semester the class had to move on the virtual platform. The lecture classes were effectively conducted on WebEx, but it became very difficult for conducting the lab works and students' performance evaluation on the online platform. The instructor adopted some new strategies to adopt with the changed environment. He recorded some video instructions for hands-on activities or lab experiments and allowed the students to bring necessary lab equipment to their residence. Thus, instead of working in the lab in small groups the students could work on the experimental activities by themselves while following the video instructions. Live prescheduled meetings on WebEx were also arranged to help them doing their labs more effectively. To evaluate the performance of the students in lab classes, the instructor arranged some oral exams over the virtual platform which are good tools for evaluating students' performance. Also, the instructor prepared a large question bank on Moodle and assigned random quizzes from that question bank to ensure a fair evaluation of students' performance. At the end of some lab classes, students were instructed to submit a short video or relevant pictures of the outcomes, and/or structured reports based on the completed hands-on activities. Those videos, pictures, and reports provided a good opportunity for the instructor looking into the students' performance.

IET 1400/2400 Technical Drafting I and II classes are two other lab-based classes which suffered from the pandemic. Both courses were offered in spring and fall 2020. Despite of several limitations the instructor managed to offer his best efforts for a good learning experience by the students. The instructor prepared and/or shared recorded video instructions for the technical drafting exercises. AutoCAD and Inventor drawing software are offered to the students for free by Autodesk. Most of the students successfully installed the respective software at their own devise. However, due to technical limitations, such as limited memory, operating systems, and poor internet service availability, few students could not install the software on their own devices. Northwestern State University kept some computer labs (following all safety protocols) open for such students, even

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during the pick of the pandemic. The face-to-face lab classes were canceled due to pandemic, and the live meeting on WebEx were conducted on scheduled time in addition to the recorded offline Moodle instructions. At the end of a scheduled lab class, the students submitted all the drawing files that they completed. For ensuring social distancing, the instructor assigned small individual projects as alternatives to a big group project. The instructor also considered oral presentation for students' semester projects, which is a proven good tool for evaluating students' performance in lab classes. The instructor prepared random drawing tests with different dimensions from a large pool of question banks. This was an effective way to ensure full participation of all students in the corresponding technical drafting classes.

Like all other faculty who teach the next generation innovators and problem solvers, authors found themselves struggling to virtually dynamic learning environment of hands-on labs. The scenario should be similar for the students [5]. To find out the opinion of the students, we surveyed the students in the laboratory courses during COVID-19 pandemic. We considered three main areas such as statements regarding overall impact of COVID-19, statements regarding hands-on teaching methods for online lab classes in engineering technology, and statements regarding "performance evaluation tools" for online lab classes in engineering technology.

Survey Results

During the pandemic, the authors applied several innovative teaching techniques to adopt with the difficult times. For getting a clear idea about the learning experience of the students a survey was conducted among the students. The survey questionnaires are grouped in three categories. The first group of questionnaire has six statements regarding overall impact of COVID-19 on the academic environment for the students. In the second group there are five statements regarding new hands-on teaching methods for online lab classes in the engineering technology department. The third group of questionnaire includes five statements regarding the *new performance evaluation tools* for online lab classes in the same department. The response of the students was collected on a 5-level Likert scale: Strongly agree, Agree, Neutral, Disagree, and Strongly disagree. The numerical equivalence for these responses is set as 5, 4, 3, 2, and 1, respectively. The objective of this survey is to identify the learning experience of the students where new leaching methods are adopted for lab-based engineering technology classes under several limitations due to COVID-19 pandemic.

Out of 54 students in the class, a total of 37 students responded to the survey questionnaire. A graphical presentation of the data is shown in Figures 1-3. Students' responses regarding overall impact of COVID-19, are shown in Figure 1. For the first statement, majority of the students (30 out of 37, or 81%) either mentioned they are neutral, or they disagree with the statement, "I have difficulties due to changes in my living condition including leaving your normal place to live". So, we consider that most of the students did not face any difficulty due to the changes in my living condition. However, more than 70% students said they are either neutral, agree or strongly agree with other five statements under this group of questionnaires. These results provide us following overall information, (a) students did not face significant difficulties due to changes in their living condition; (b) students feel stressed thinking about the adverse effect of COVID-19 pandemic on their academic performance; (c) they had full access to the required software resources to support

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my remote learning; (d) since the move to online instruction students spent more time studying compared to pre-pandemic era; (e) students' access to the lab rooms should be controlled to ensure everyone's safety from COVID-19; and (f) the HyFlex method of teaching is NOT effective for lab based courses.

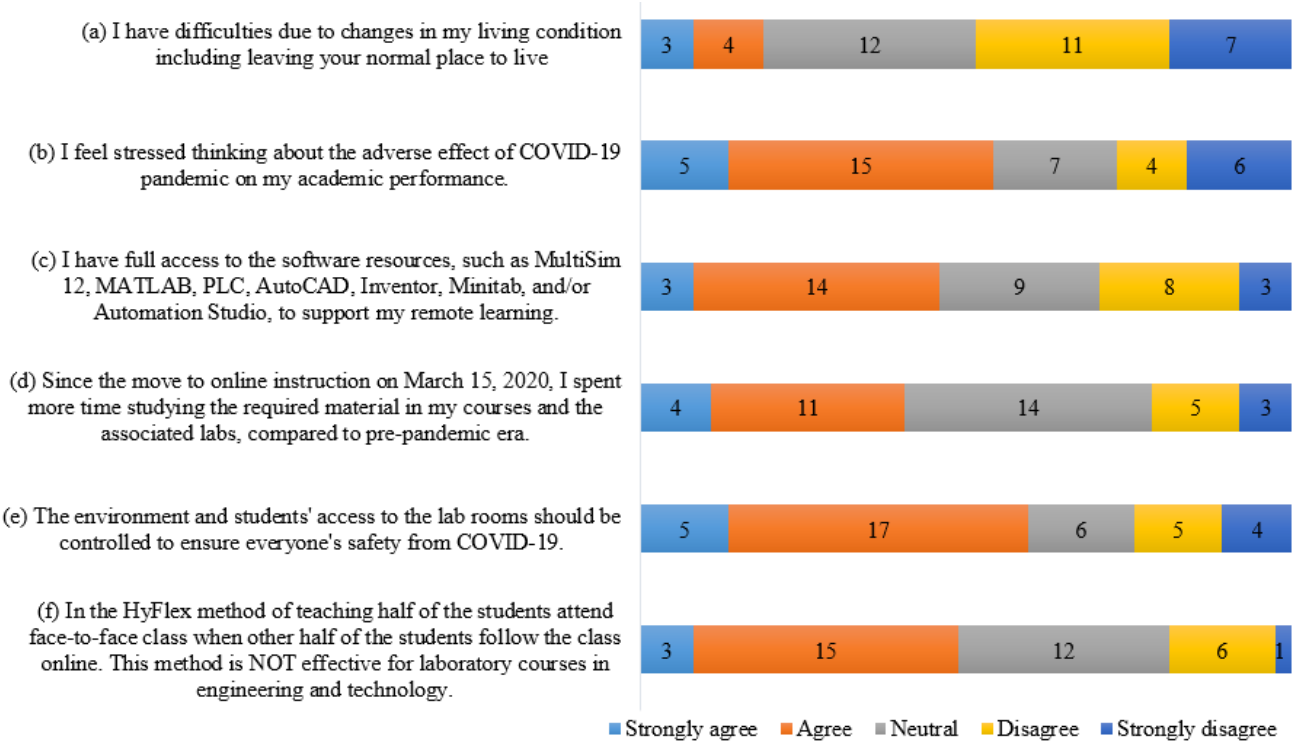

Figure 1. Students' response regarding overall impact of COVID-19.

In Figure 2 we have summarized the students' responses regarding newly introduced hands-on teaching methods for online lab classes. In this category of questionnaire, we observe that about 75% to 92% (28 to 34 out of 37) students said they are either neutral or more than just neutral (agree or strongly agree) to four out of five statements. These data illustrate that, students liked recorded video instructions for hands-on activities or lab experiments [Figure 2 (a)]. They also liked the simulation and other software which help them experience a good learning environment, especially when physical experiments in the labs are not safe due to pandemic [Figure 2 (b)]. Small individual projects are also supported by the students, as alternatives to a big group project [Figure 2 (d)]. Students' responses also give us a positive vibe towards live meeting on WebEx and other virtual platforms. However, at least 49% (18 out of 37) students think that it is not effective to bring lab equipment or get software access at home [Figure 2 (c)]. They disagreed with the given statement regarding this issue and expressed their acceptance for working at the lab-rooms in small groups.

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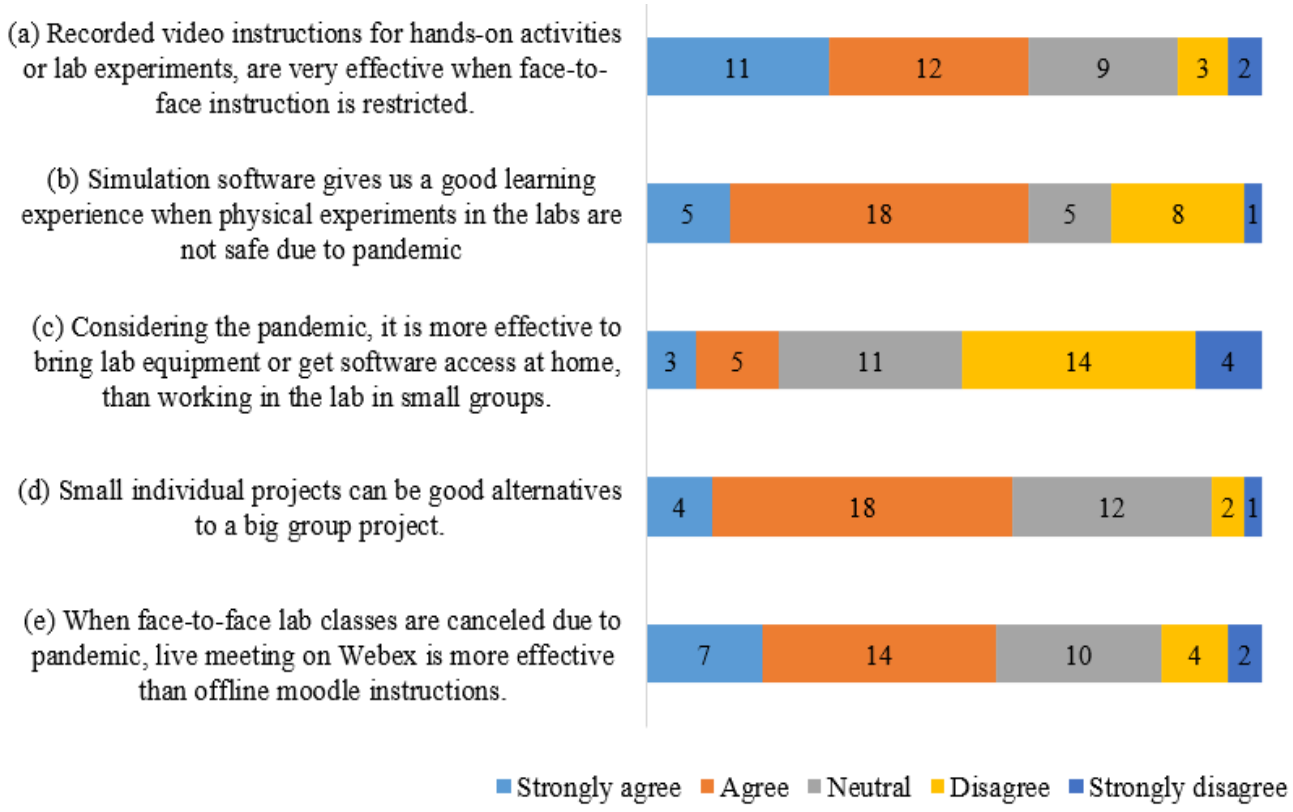

Figure 2. Students' response regarding hands-on teaching methods for online lab classes.

Figure 3 presents the students' responses regarding "performance evaluation tools" for online lab classes. In this figure we see that the students are mostly neutral to their performance evaluation method. They even did not show any significant disagreement to the statement given in the survey. From the output of this survey, we conclude that for fair evaluation of students' performance we can move forward with the following techniques during the pandemic.

(a) Oral presentation and oral examination
(b) Random quiz from large question bank
(c) Structured report writing
(d) Personalized (individual) lab test/experiment with random experimental setup
(e) Short video/pictures submission from completed lab work outcomes.

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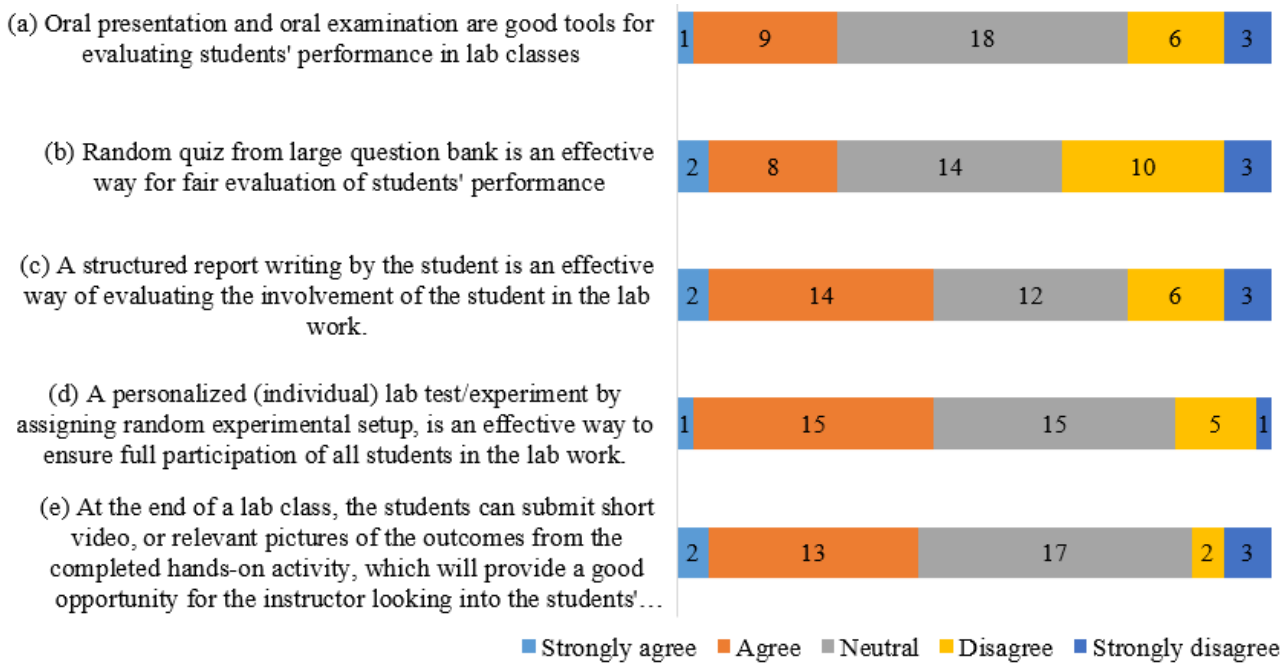

Figure 3. Students' response regarding "performance evaluation tools" for online lab classes.

It was hypothesized that the students' responses are more than just neutral (either Neutral, Agree or Strongly Agree) towards the new methods of teaching. Thus, the null and alternate hypothesis becomes,

Null hypothesis: $H_0: \mu \geq 3$

Alternate hypothesis: $H_1: \mu < 3$

To test the hypothesis, we translated the linguistic responses to numerical values and calculated mean and variances for each questions in the survey. One-sample t-tests are conducted to test the hypothesis, with level of significance α=0.05, and critical test statistics, $t < -1.688$ with degree of freedom = 36. Thus, we reject our null hypothesis H_0 if t<-1.688, and accept the alternate hypothesis H_1: $\mu < 3$. Otherwise, we cannot reject our null hypothesis.

All the survey question and the summary of the results are presented in Table 1. It is observed that the hypothesis for only the first question is rejected. This result indicates that a statistically significant percentage of students from the survey group was not reporting difficulties. The null hypothesis for other questions can not be rejected with sufficient evidence. Thus, we conclude that the students mostly agreed with the new teaching methods we made to adopt with the COVID-19 pandemic.

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Table 1. Survey questionnaire and results for consequence of COVID-19 on Engineering Technology Lab classes. *[Hypothesis testing parameters: observations = 37, df = 36, H_0: $\mu \geq 3$, H_1 : $\mu < 3$; Reject H_0 if $t < -1.688$, $\alpha = 0.05$]*

1. Please choose how much you agree or disagree with the following statements regarding overall impact of COVID-19.										
	Strongly agree (5) %	Agree (4) %	Neutral (3) %	Disagree (2) %	Strongly disagree (1) %	Mean	Var	t Stat	P(T≤t) one-tail	Decision
I have difficulties due to changes in my living condition including leaving your normal place to live	8.11	10.81	32.43	29.73	18.92	2.59	1.36	-2.12	0.0207	Reject H_0
I feel stressed thinking about the adverse effect of COVID-19 pandemic on my academic performance.	13.51	40.54	18.92	10.81	16.22	3.24	1.69	1.14	0.8688	Cannot reject H_0
I have full access to the software resources, such as MultiSim 12, MATLAB, PLC, AutoCAD, Inventor, Minitab, and/or Automation Studio, to support my remote learning.	8.11	37.84	24.32	21.62	8.11	3.16	1.25	0.88	0.8082	Cannot reject H_0
Since the move to online instruction on March 15, 2020, I spent more time studying the required material in my courses and the associated labs, compared to pre-pandemic era.	10.81	29.73	37.84	13.51	8.11	3.22	1.17	1.21	0.8836	Cannot reject H_0
The environment and students' access to the lab rooms should be controlled to ensure everyone's safety from COVID-19.	13.51	45.95	16.22	13.51	10.81	3.38	1.46	1.90	0.9674	Cannot reject H_0
In the HyFlex method of teaching half of the students attend face-to-face class when other half of the students follow the class online. This method is NOT effective for laboratory courses in engineering and technology.	8.11	40.54	32.43	16.22	2.70	3.35	0.90	2.25	0.9847	Cannot reject H_0
2. Please choose how much you agree or disagree with the following statements regarding hands-on teaching methods for online lab classes in engineering technology.										
	Strongly agree (5) %	Agree (4) %	Neutral (3) %	Disagree (2) %	Strongly disagree (1) %	Mean	Var	t Stat	P(T≥t) one-tail	Decision
Recorded video instructions for hands-on activities or lab experiments, are very effective when face-to-face instruction is restricted.	29.73	32.43	24.32	8.11	5.41	3.73	1.31	3.87	0.9998	Cannot reject H_0
Simulation software gives us a good learning experience when physical experiments in the labs are not safe due to pandemic	13.51	48.65	13.51	21.62	2.70	3.49	1.15	2.76	0.9955	Cannot reject H_0
Considering the pandemic, it is more effective to bring lab equipment or get software access at home, than working in the lab in small groups.	8.11	13.51	29.73	37.84	10.81	2.70	1.21	-1.64	0.0548	Cannot reject H_0
Small individual projects can be good alternatives to a big group project.	10.81	48.65	32.43	5.41	2.70	3.59	0.75	4.18	0.9999	Cannot reject H_0
When face-to-face lab classes are canceled due to pandemic, live meeting on Webex is more effective than offline Moodle instructions.	18.92	37.84	27.03	10.81	5.41	3.54	1.20	3.00	0.9976	Cannot reject H_0

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Table 1 continued …….

3. Please choose how much you agree or disagree with the following statements regarding "performance evaluation tools" for online lab classes in engineering technology.

	Strongly agree (5) %	Agree (4) %	Neutral (3) %	Disagree (2) %	Strongly disagree (1) %	Mean	Var	t Stat	P(T≥t) one-tail	Decision
Oral presentation and oral examination are good tools for evaluating students' performance in lab classes	2.70	24.32	48.65	16.22	8.11	2.97	0.86	-0.18	0.4302	Cannot reject H_0
Random quiz from large question bank is an effective way for fair evaluation of students' performance	5.41	21.62	37.84	27.03	8.11	2.89	1.04	-0.64	0.2619	Cannot reject H_0
A structured report writing by the student is an effective way of evaluating the involvement of the student in the lab work.	5.41	37.84	32.43	16.22	8.11	3.16	1.08	0.95	0.8251	Cannot reject H_0
A personalized (individual) lab test/experiment by assigning random experimental setup, is an effective way to ensure full participation of all students in the lab work.	2.70	40.54	40.54	13.51	2.70	3.27	0.70	1.96	0.9712	Cannot reject H_0
At the end of a lab class, the students can submit short video, or relevant pictures of the outcomes from the completed hands-on activity, which will provide a good opportunity for the instructor looking into the students' performance.	5.41	35.14	45.95	5.41	8.11	3.24	0.91	1.55	0.935	Cannot reject H_0

Summary and Conclusions

Further in-depth analysis of the data gives us more insight about the students' feelings and impressions to the new teaching environment and new methods of teaching for lab-based classes in the Engineering Technology department. The hypothesis is again redefined in another way such that, Null hypothesis: H_{00}: $\mu \leq 3$, and Alternate hypothesis: H_{11}: $\mu > 3$. As we tested this new hypothesis, we found statistically significant supports to the new alternate hypothesis H_{11}: $\mu > 3$ for some survey questions and found strong evidence to reject new null hypothesis H_{00}: $\mu \leq 3$ for the respective questions. From here we conclude with 95% confidence (α=0.05) that, the engineering technology students at Northwestern State University accepted most of our activities to improve their learning experience during the pandemic. Based on this research and survey findings we conclude with the following recommendations:

(1) The environment and students' access to the lab rooms should be controlled to ensure everyone's safety from COVID-19,
(2) The HyFlex method of teaching should not be followed for lab-based courses in engineering and technology,
(3) some recorded video instructions for hands-on activities or lab experiments, need to be prepared and shared with the students,
(4) students' access to the relevant simulation and other software should be provided to improve remote learning experience,
(5) in place of big group project, the instructor should assign small individual lab/semester projects,

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(6) live meeting on the virtual platform should be continued in addition to offline recorded instructions,
(7) personalized (individual) lab test/experiment with random experimental setup should be assigned to the students to ensure their full participation in the lab work.

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