Evidence of productivity recovery among undergraduate industrial engineering students during the Covid-19 pandemic in the Philippines

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ABSTRACT: The Covid-19 pandemic has impacted on various aspects of education across the world. The study outlined in this article was focused on the changing level of students' productivity in the Philippines at the inception and duration of the pandemic. Work sampling was employed to quantify and analyse the time spent by undergraduate industrial engineering students on their academic and personal activities as a measure of productivity during the pandemic. It was found that students exhibited productivity recovery, that is, the time they spent on academic activities after a year of remote learning was higher relative to during the emergency transition to remote learning at the beginning of the pandemic. The analysis of the multilevel categories of activities, both academic and personal, revealed that the productivity increase can be attributed to the adjustments made by the instructors taking advantage of synchronous classes, self-regulation and improved time management of students, and enforced student identity in a learning-from-home setup.

INTRODUCTION

With a major disruption in the learning process due to a sudden shift to remote learning during the Covid-19 pandemic, information on the level of productivity of students, much more on how productivity changes as the pandemic continue and remote learning ensues, is critical. While many studies examine the effects of the pandemic among students, only a few attempted to quantify productivity or study time, and most relied on survey questionnaire data.

In this study, productivity was measured through the proportion of academic activities, and its complement, personal activities through a technique called work sampling. As students face difficulties with fulfilling their academic responsibilities due to demands at home [1-5], the amount of time spent studying is an important student-controlled factor that contributes to academic success.

Based on the literature search by the authors, there are no non-survey questionnaire-based studies that measured the productivity of higher education students during the Covid-19 pandemic. With these as a backdrop, this study was focused on measuring the productivity of undergraduate students during the transition to, and after a year of remote learning, designated as year 1 and year 2 in this study, respectively. Further, the authors offer insights on the changes in time spent on the various dimensions of activities in the context of the pandemic, the University controls implemented in response to the pandemic, and the practices employed by the instructors during remote learning.

STUDY CONTEXT

The University of the Philippines (UP) is the country's national university, and similar to other academic institutions had to adapt its operations in view of the looming threat of the Covid-19 virus. At the core of the response to the pandemic for education, the University implemented remote course delivery. A major deliverable that was required from faculty members before the start of classes during year 1 were the so-called *course packs*, which became the primary means of delivering content to students.

A course pack contains a detailed syllabus of a course, learning materials, and activity and assessment guides. It is a complete and comprehensive set of materials:

…intended to support guided independent learning... that ... allow the faculty to focus on monitoring student progress [5].

Significant revisions in academic policies were also implemented. The most notable among these are the *no-fail policy*, the suspension of course prerequisites and optional attendance to synchronous classes [6].

Meanwhile, a semi-structured survey answered by the instructors of three major industrial engineering courses, two of which have a laboratory component, revealed two primary implemented practices which were adjusted from year 1 to year 2. These are increased frequency and regular conduct of synchronous classes and increased number of assessments. For the former, synchronous classes were conducted during regular class hours once to twice a week in year 2 from less than once to only once a week in year 1 as preferred by some students and the instructors to establish routine among students and improve monitoring of students' learning outcomes through attendance.

For the latter, the number of major assessments including examinations, modular assessments or laboratory exercises increased, effectively decreasing the topics covered per assessment, this practice improved monitoring of students' learning outcomes through submissions. Among the many items identified by the instructors, the mentioned practices are common among the courses and directly influence the measured statistic of this study.

DATA AND METHODS

Participants

Participants were all the students taking up the Batchelor of Science (BS) degree in industrial engineering with sophomore standing from where a total of 53 (out of 62) and 57 (out of 60) validated samples were collected in year 1 and year 2, respectively. Most of the participants (41 in year 1 and 46 in year 2) were aged 19 and 20 and had an average course load of 18 units, equivalent to about five courses in both the study periods. The participant distribution by sex-at-birth was about the same for both years (55% male, 45% female in year 1, and 54% male, 46% female in year 2).

During the study period, all participants were living with their family members, except for four students who were living alone in year 1. In terms of remote learning requirements, one participant in year 1, and two in year 2 used mobile data only, while the rest were connected through pocket-WiFi or had DSL/fibre connections. For the device used, all students had either a laptop, desktop or tablet, except for one student who used a basic mobile phone only, and another one who used a smartphone only in year 1.

Data collection technique

The data collection technique used in this study is called work sampling. It is a work measurement approach that can examine multilevel categories to analyse activities in detail. This established methodological approach measures accurately and precisely the percentage of time people spent on a predefined set of activities. This is calculated by identifying and recording an activity at random times and taking a sufficiently large sample. It is based on a binomial experiment consisting of n repeated trials, where the result is either a success or a failure (in this study, of observing a given activity), wherein the probability of success is denoted by p. Equation 1 below was used for calculating the percentage time for an activity, and Equation 2 for the number of samples required. The greater the number of sample points, the more precise the estimates of the time percentages are obtained.

$$Estimated\ percentage\ of\ time\ spent\ in\ activity\ x = \frac{Total\ number\ of\ data\ points\ at\ which\ activity\ x\ was\ observed}{Total\ number\ of\ data\ points\ observed} \quad (1)$$

$$n = \left(\frac{z}{e}\right)^2 p(1-p) \quad (2)$$

Where: n is the required number of samples;
z is the coefficient of the confidence interval;
e is the degree of allowable error in p;
p is the proportion of time spent in an activity.

In this study the overall-level approach of work sampling was employed [2], where data from all participants are aggregated to calculate time percentages. This approach enables larger volume analyses, where greater weight is given to the most precise data which is appropriate for the study's goal of investigating the productivity of students and how it changed during the pandemic collectively as opposed to individually.

Data and Study Schedule

The total frequencies collected for year 1 and year 2 were 27,726 and 31,196, respectively, resulting in a less than 1% error and 95% confidence interval. Participants gathered 523 (year 1), and 547 (year 2) data points on the average over 10 consecutive weekdays, two weeks before the final examinations.

Activities of Interest

The primary categories of interest in the study were academic activities and their natural complement, personal activities. The secondary level categories under each were developed based on the activities of students on a typical day.

Academic activities are tasks that directly advance student success, including studying and accomplishing requirements, among others. Meanwhile, personal activities include non-academic tasks. The second level categories of academic activities coded as A, and personal activities coded as B, are detailed in Table 1.

Table 1: Descriptions of academic activities and their secondary categories.

Category (code)	Description
Studying/learning (A1)	Reading/reviewing class materials, attending synchronous activities (i.e. live discussions and synchronous assessments)
Consulting with the instructor (A2)	Communicating with the instructor using any medium, usually to ask a question or seek supplement information
Discussing with other student/s (A3)	Communicating with other students using any medium to ask a question or seek supplement information
Accomplishing requirements (A4)	Working on class requirements (i.e. quiz, modular assessment, exercise, project, etc) asynchronously
Chores (B1)	Household tasks and errands
Extracurricular (B2)	Active reading, consuming news, fulfilling responsibilities as part of an organisation
Self-care (B3)	Exercising, meditating, skin/body care
Rest and recovery (B4)	Sleeping, taking a nap, resting/doing nothing, eating
Entertainment (B5)	Watching shows, listening to music, browsing social media and other Web sites/applications
Socialising (B6)	Gaming, communicating/connecting with family and friends

Procedure

Before the study, participants underwent an orientation session administered by the researchers. During the session, the rationale of the experiment was explained, and participants were given pertinent instructions. First was defining their 12-hour workday, this was important as study hours can be different between students. Next was computing the initial number of samples to create a preliminary sampling plan in which an initial estimate of p of 40%, 95% confidence interval, and 4% error parameter values was used. The number of samples was equally divided into the number of days of data collection to determine how many data points needed to be collected and the random time to generate in a day.

For a more accurate study, the sampling plan was updated every two days of data collection by using the data points collected by far, specifically in calculating the value of p. For determining the specific time of collecting data, an on-line random time generator was used. The students were advised to set their alarm during the generated random times, except for when they have scheduled live discussions to avoid distraction. Random times that fell on this duration were automatically recorded under category A1.

Other data were recorded in their respective category when they were notified through the alarm. Data from each participant were carefully screened before analysis and data sets with significant irregularities (i.e. highly varied work hours, missing values) and included weekends were removed.

Statistical hypothesis tests were conducted on the total proportion of activities, and proportions of secondary categories of academic and personal activities. For the total proportion, it was hypothesised that the year 2 time percentage for academic activities was greater than year 1 ($p2 > p1$) as students needed to cope with a new situation during the pandemic and adjust after a year of remote learning.

For the secondary categories, as it does not necessarily follow that if total $p2 > p1$, then all categories of activities in year 2 are greater than year 1 (e.g. year 2 may have increased studying and at the same time decreased browsing), it was deemed necessary to investigate two alternative hypotheses, which were $p2 > p1$, and $p1 > p2$. A 95% level of confidence and an alpha of 5% was used for the test. The results were interpreted in the context of the pandemic, the University's response to the pandemic, and the department's practices during the studied semesters.

RESULTS

The results of the 2-proportion test on the total academic activities p shown in Table 2 reveal that there is sufficient evidence to conclude that year 2 productivity is higher compared to year 1. Converting the proportion values to time considering a 12-hour workday, there is an increase of almost an hour dedicated to academic activities for those who have a year of experience with remote learning during the pandemic.

Table 2: Results of 2-proportion test on total academic activities, *p*.

Remote learning year	Total sample	Successful events, academic activities	p	*Time equivalent (hours)	Difference (minutes)
1	27726	10321	0.3722	4.47	+ 55.56
2	31196	14020	0.4494	5.39	
Is $p2 > p1$?	Yes				
p-value	0.000				

*Based on a 12-hour workday

Analysing the details of the academic activities is essential in identifying the contributors to the change in the total proportion presented above. Looking at the details shown in Table 3, the primary driver of the increase in the total proportion of productive time is category A1, which includes dedicated time for self-study and learning in the virtual classroom.

Examining the next three activity categories, which pertain to student-faculty interaction outside class hours, student-student interaction outside class hours and dedicated time for completing course requirements, the hypothesis test suggests that the proportion of time dedicated to these activities is significantly higher for year 1. Looking at the difference in time spent on the activities based on a 12-hour workday, it is apparent that category A4, which includes dedicated time for working on requirements, also significantly affected the total productive time, although in the opposite direction, where there is a decrease of about 24 minutes spent by students in year 2.

Table 3: Summary of 2-proportion test on categories of academic activities, *p*.

	Year 1			Year 2			***Is $p2 > p1$?	***Is $p2 < p1$?	Difference (minutes)
	Successful events	p1	**Time equivalent (hours)	Successful events	p2	**Time equivalent (hours)			
Total samples	27726			31196					
*A1	3135	0.1131	1.36	7483	0.2399	2.88	Yes	No	+ 91.30
*A2	153	0.0055	0.07	103	0.0033	0.04	No	Yes	- 1.60
*A3	869	0.0313	0.38	520	0.0167	0.20	No	Yes	- 10.59
*A4	6164	0.2223	2.67	5915	0.1896	2.28	No	Yes	- 23.55

*Studying/learning (A1); Consulting with instructor (A2); Discussing with other student/s (A3); Accomplishing requirements (A4); **Based on a 12-hour workday; ***Yes *p*-value = 0.000; No *p*-value = 1.000

Another important dimension to investigate is the complement of the academic activities, which is the personal activities or 1-*p*, and its details. Among the activities, category B4 which consists of activities essential to maintaining a student's well-being is the only category whose proportion is greater for year 2. For categories in which the proportions are less in year 2, the greatest decrease can be observed in category B6, which consists of social activities including gaming and connecting with friends and family members, with an equivalent reduction of more than 26 minutes per day. Additionally, the time spent for categories B1 (chores), B5 (entertainment), and B3 (self-care) also decreased by more than 10 minutes per day. Table 4 shows the summary of the test for personal activities.

Table 4: Summary of 2-proportion test on categories of personal activities, 1-*p*.

	Year 1			Year 2			***Is 1-$p2 > 1-p1$?	***Is 1-$p2 < 1-p1$?	Difference (minutes)
	Successful events	1-p1	**Time equivalent (hours)	Successful events	1-p2	**Time equivalent (hours)			
Total samples	27726			31196					
*B1	2912	0.1050	1.26	2747	0.0871	1.05	No	Yes	- 12.89
*B2	1202	0.0434	0.52	1165	0.0373	0.45	No	Yes	- 4.33
*B3	1689	0.0608	0.73	1432	0.0468	0.56	No	Yes	- 10.11
*B4	5188	0.1871	2.24	6209	0.1990	2.39	Yes	No	+ 8.58
*B5	3444	0.1242	1.49	3413	0.1094	1.31	No	Yes	- 10.66
*B6	2975	0.1073	1.29	2214	0.0709	0.85	No	Yes	- 26.15

*Chores (B1); Extracurricular (B2); Self-care (B3); Rest and recovery (B4); Entertainment (B5); Socialising (B6); **Based on a 12-hour workday; ***Yes *p*-value = 0.000; No *p*-value = 1.000

DISCUSSION

This study's goal was to provide evidence of productivity recovery among college students taking a BS industrial engineering curriculum after experiencing remote learning for a full academic year with the backdrop of some studies

that found a decline in study hours spent by students due to a sudden shift to on-line learning brought about by the pandemic.

In this study, it was found that students show indications of productivity recovery as measured through the proportion of academic activities spent considering a 12-hour workday. Additionally, the measurement of the proportion of time spent on the various categories of personal activities, which naturally take time away from academic activities, is an important contribution of this study. Figure 1 illustrates the composition of all activities in a 12-hour working day for year 1 and year 2.
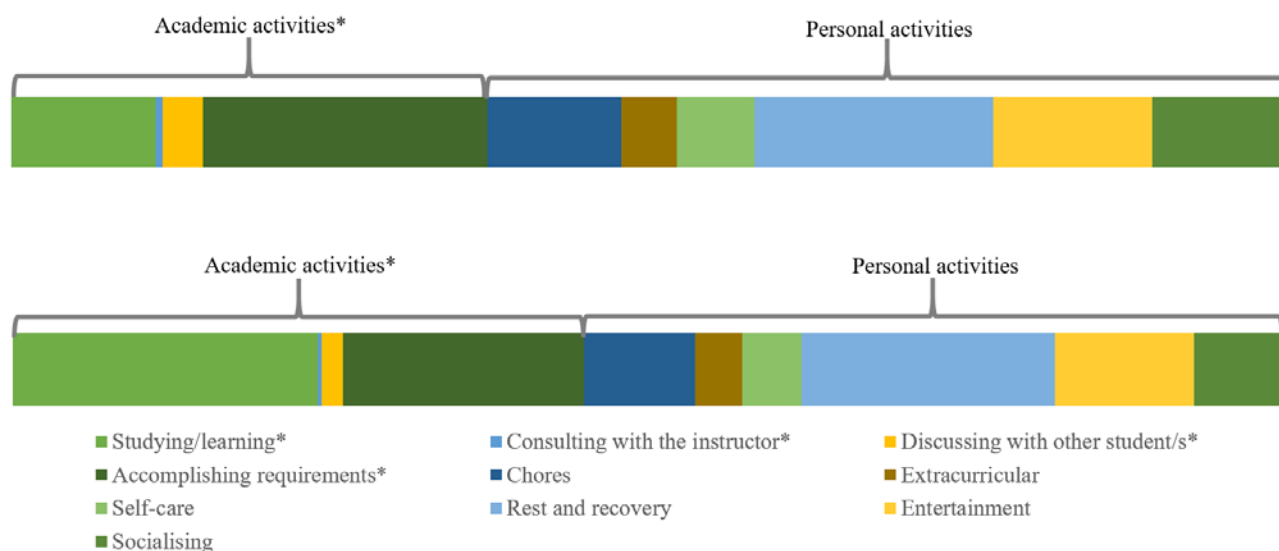

Figure 1: Comparison of the composition of activities in a 12-hour workday of year 1 (top) and year 2 (bottom).

The most notable change between year 1 and year 2 is the significant increase in time spent studying/learning (A1). It is to be noted that during year 1, the prevalent mode of delivering course content is mostly asynchronous, which is in line with the University's directive to prioritise inclusivity and provide maximum flexibility among students during remote learning through the course packs which allows for independent learning [5].

This mode is also aligned with the preference of students, where eight out of 10 prefer watching pre-recorded video lectures, and only five out of 10 prefer participating in live on-line lectures based on the survey conducted by the college offering the BSIE curriculum during year 1 [7]. On the contrary, based on the practices of instructors of IE major courses in year 2, the frequency of conducting synchronous classes doubled, although the attendance to live discussions remained optional [6] with the flexibility of viewing a recorded one at a later time. The primary motivation for this is increasing engagement in class and [re]introducing structure and routine to students. With the significant increase in time spent in this activity, it can be concluded that students prefer attending synchronous classes.

Another substantial change in academic activities includes reduced time spent working on requirements (A4). This result suggests that students seem to be more efficient in accomplishing their requirements given that there are more requirements compared to year 1. Nonetheless, this can also be attributed to the reduced scope per requirement, as per the practice of IE course instructors, as well as the fact the other requirements were completed synchronously. Concerning this, student feedback in year 2 suggests that delivering assessments synchronously is not preferred, with many of them saying that completing the assessments needs more time than what was given [8]. Synthesising, while the instructors intend to improve student discipline through synchronous accomplishments of requirements, it results in dissatisfaction among students.

Meanwhile, for personal activities, the most notable change is the decrease in social interaction (B6). Related to this, the student-to-student academic interaction outside synchronous classes (A3) lessened as well. The effect on the mental health of students during the pandemic called for social support and interaction with family and friends, through communication albeit digitally to ease the negative feelings, such as loneliness and anxiety, brought about by isolation [4][9]. In this study, a decline was noted in this adaptive coping strategy suggesting that students are more adjusted to remote learning during year 2. This is consistent with the UP-student survey results conducted by the Office of the Vice President for Academic Affairs (OVPAA), where 61% of the students responded that they feel adjusted to remote learning [10]. Additionally, a decline was also observed for self-care activities (B3), including exercising, which were also considered in the study of Rosen et al [3] as adaptive coping strategies. These are important findings suggesting self-regulation among students in year 2.

The results also showed a decrease in passive screen time (B5) from year 2 to year 1. In contrast with connecting with peers through actively communicating, content consumption generally affects students negatively leading to increased loneliness [4] and vulnerability to pandemic-related stressors, or simply takes away time from other more important

behaviours, such as exercising, sleeping, or connecting with friends and family [3] and in the context of this study, time spent for academic activities. This can also explain the increase in the rest and recovery activities (B4), where the decrease in passive screen time led to the increased time spent on rest.

The study also revealed a decrease in time spent on chores and errands (B1) of students who are learning from home in year 2. The shift to remote learning prompted students to return home and live with their families where different roles, such as child and/or sibling in addition to being a student were assumed [1]. Consultations with UP students in June 2020 revealed this similar concern where students on learning from home setup are subjected to …*multiple demands of family members* [5]. The decline in time spent on chores and errands suggest that the student role is more emphasised during year 2. This may be attributed to the more regular conduct of synchronous activities in year 2, which is one of the measures that enforce the student identity role [1].

Lastly, the activity categories consulting with instructors (A2) and extra-curricular activities (B2), not only represent the lowest change (decrease) in academic and personal activities, respectively, but also the lowest proportion in their respective categories in both years. Generally, this study reveals that students do not actively engage in one-on-one consultation with instructors outside synchronous classes. On the other hand, engaging in productive reading and extracurricular activities do not negatively impact the time spent on academic activities, as in taking time away from study hours, especially for year 2 where there is less time spent in this activity; this is expected as the student must prioritise their academic load.

CONCLUSIONS

This study's strength is the use of a technique that accurately measures the time students allot for multilevel categories of activities, a feature that cannot be found in other studies. This sets a precedent for future researchers whose studies will benefit from an accurate measurement of time spent by students in various activities.

Overall, this study reveals that students show indications of recovery of their productivity after a year of remote learning evident in an increase in total time spent on academic activities. Important insights were made evident from the change in the distribution of time percentages in various activities from year 1 during the shift to remote learning to year 2 after experiencing remote learning for a full academic year.

First and the most recognisable is the instructors' practice of increasing and making synchronous interaction more regular, almost like how traditional face-to-face classes are conducted, significantly increasing students' learning time suggesting that students preferred attending live discussions during scheduled class hours despite being optional in year 2. Nonetheless, while synchronous classes were generally beneficial, assessments administered synchronously created dissatisfaction among students.

Second, students show indication of being more self-regulated evident in less time spent connecting with social support groups including family and friends compared to the transition period to remote learning.

Third, improvement in time management skills is manifested through less passive screen time and more time for rest and recovery among students.

Lastly, the student role has dominated over other roles that a student fulfils at home decreasing the time spent on chores.

This study's findings contribute to addressing the pandemic specifically in the education sector as educators and policymakers reflect on the opportunities of pushing remote learning forward toward the new normal.

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BIOGRAPHIES

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