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It's About Time: An Analysis of Student Activities Under Remote Learning

Bradley J. Sottile, Pennsylvania State University

Brad Sottile is Lecturer in Computer Science and Engineering, and Aerospace Engineering in The Pennsylvania State University's College of Engineering, School of Electrical Engineering and Computer Science.

Laura E. Cruz, Pennsylvania State University

Laura Cruz (Ph.D, UC Berkeley 2001) is an Associate Research Professor for Teaching & Learning Scholarship with the Schreyer Institute for Teaching Excellence at Penn State. She previously served as the director of two Centers for Teaching and Learning; as editor-in-chief of three teaching-related journals, as elected member of the national board for faculty developers in the United States, and as principle investigator for four externally funded grants. Her publications and invited presentations include work in her first discipline (history) as well as the areas of instructional design, educational development, organizational change, and educational innovation. Her most recent co-authored book, Taking Flight: Making your Center for Teaching and Learning Soar was just published by Stylus Press.

Dr. Yi-An Lo Burleson, Pennsylvania State University

Yi-An Burleson (Ph.D. in counseling psychology, West Virginia University, 2013) is an Assistant Professor of psychology at Pennsylvania State University, Beaver, She has previously served as an assistant professor and program director, or psychologist and international student services and career coordinator at universities. She has had presentations in teaching and learning, prevention, and multicultural counseling and teaching. Clinically, she has provided individual, group, career, and couples therapy to clients age ranging from 3 to 74 at counseling centers, community mental health agencies, and group and private practices.

Kris McLain, Pennsylvania State University

Kris McLain is a dual-title PhD candidate in Philosophy and Women's, Gender, and Sexuality Studies. Her research lies at the intersections of feminist philosophy, trans and queer theory, and ancient philosophy. Her dissertation explores the metaphor of gestation for collective practices of knowledge creation.

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Abstract

Numerous surveys, both internal and external, have indicated that many students are struggling with time management under COVID-19 conditions, and that their normal pattern of activities, such as sleep, exercise, and studying, have been disrupted. Even prior to the pandemic, each of these factors (e.g. sleep, exercise, and studying) have been identified as critical for student success, yet, to date, there are no studies that address the shifts in student time allocation that may have taken place under the current, unprecedented conditions of remote learning.

For this IRB-approved study, we collected evidence of how students are allocating their time (e.g. what activities and for what duration), using online time diaries completed by students enrolled in several online (synchronous and asynchronous) undergraduate engineering courses. The present study builds on previous studies that analyzed the nexus between student activity patterns (e.g. sleep, studying, exercise, eating) and learning to ascertain changes in these patterns that have occurred under the new pedagogical (and broader global) conditions. Our findings are intended to inform human-centered course design, to optimize student well-being, and – by extension – learning under the conditions of remote/multi-modal learning and beyond.

Introduction

It is fair to say that COVID-19 has upended higher education, causing numerous disruptions and leading to uncertain futures for institutions and individuals. The higher education press, as well as emerging research, has placed a great deal of emphasis on the challenges faced by faculty and students through the shift to remote teaching. Numerous surveys, both internal and external to institutions, have indicated that many students are struggling with time management under these conditions, as their normal patterns of activities, such as sleep, exercise, and studying, have been disrupted. The present study seeks to gather direct evidence of how students are allocating their time (e.g. what activities and for what duration), in an effort to both inform human-centered course design and to optimize student learning and well-being under the conditions of remote/multi-modal learning and beyond.

Literature Review

Until relatively recently, there has been little scholarly interest in how students spend their time outside of class. This began changing in the late 1990's and early 2000's when a handful of large-scale studies indicated that student spend far less time on learning activities, such as reading or studying, than had been previously believed [1]. These studies served not only as the basis of considerable intervention efforts, but they further underscored the research potential of time as the subject of educational research. Researchers became increasingly interested in measuring the length of time spent on activities that were closely linked to student success, such as sufficient sleep, regular exercise, and appropriate levels of individual or group studying, levels of which were reported directly by students through structured time diaries [2], [3], [4], [5], [6].

The present study seeks to build on these previous studies to ascertain changes in the temporal patterns that students have experienced under the new pedagogical and broader social conditions of remote learning and the global COVID-19 pandemic. There are several reasons to believe that these patterns may have changed. First, long-standing research had already indicated that time management is a persistent obstacle for students in online classes [7], [8]. The more self-directed nature of most online pedagogical models presents significant challenges to students who struggle with time management, especially exhibited in behaviors such as procrastination and missing deadlines. Popular interventions to address this challenge include time management training and readiness assessments that include evaluation of time management skills [9]. The rapid onset of remote teaching has, unfortunately, largely precluded the widespread adaption of these proactive strategies.

It is questionable, too, whether or not the adaption of such proactive strategies would continue to be effective under the conditions of the global COVID-19 pandemic, as they had not previously been assessed on students undergoing the unprecedented conditions of collective trauma. The relatively small subfield of trauma-informed pedagogy has risen to the fore over the past year, and research in this area suggests that students who have experienced (or who may be currently experiencing) trauma(s) will likely struggle not only with time management, but more broadly with related executive-functions such as planning and problem-solving [10], [11]. It is certainly possible that we are only learning about the long-term effects of the combination of trauma and quarantine; Holman and Grisham [12] previously noted that "altered perceptions of time and its passing are common experiences of people facing trauma." Those altered perceptions may include "perceptual distortions such as feeling like time has stopped or that everything is in slow motion, experiencing a sense of timelessness, confusing the order of time and days, and perceiving a foreshortened future" [13].

This latter challenge may be especially salient, as future orientation has been identified as a critical component of both mental health and academic success. Emerging studies of student life under global pandemic conditions have suggested that they are experiencing issues of well-being, such as depression and anxiety, at rates that are likely higher than the general population in the United States [14], [15]. While some of the causes may be situational (e.g. isolation, economic insecurity, family issues, etc.), others may be related to their developmental stage, especially the social limitations imposed on traditionally-aged (18-24 year old) college students [16]. Both disorders are associated with changing patterns of activity, such as more sleep, less exercise, and decreasing engagement in social activities.

Nearly all studies of the student experience under COVID-19 conditions have relied on self-reported survey data. There are several likely reasons for this, including both expediency (surveys can be implemented relatively quickly) and reliability (previously validated surveys are widely available). These survey instruments were validated, however, under conditions markedly different than what students are currently facing, and so may omit critical factors that have emerged only recently. Similarly, educational researchers recognized the significant limitations of student self-report of learning well before the pandemic, and the known issues of construct validity, social desirability bias, and sampling/response rates, are likely exacerbated under the conditions of extended quarantine [17], [18], [19].

This study utilizes an established alternative assessment approach, time diaries, to mitigate these known methodological issues. While the use of time diaries does not fully remove the biases inherent in self-reported student data, we argue that they provide a more authentic form of assessment in that the students are not being asked to report on the outcomes being assessed, i.e. wellness and learning, but rather to provide evidence of tangible changes in behavior that the researchers can associate with these outcomes *ex post*. To further mitigate issues of social desirability and topic selection bias, the time diaries are holistic, i.e. the students were asked to record all of their activities in 30-minute intervals over the course of two days. As previous time diary studies have demonstrated, students do not learn in a vacuum, and this approach is intended to be more integrative and – by extension – more authentic, than studies that focus on learning or well-being alone. Our findings suggest that students are not only spending their time under quarantine in ways that faculty and administrators may not expect, but their collective diaries suggest more fundamental changes of time and temporality that are likely to persist well after the global COVID-19 pandemic recedes from the forefront of our lives.

The Context

The Pennsylvania State University (Penn State), where this study was conducted, is a large, public, multi-campus, research-intensive institution located in a semi-rural region of the northeastern United States. The University's response to the onset of the global COVID-19 pandemic was fairly typical of institutions of similar type, size, and location. Prior to the Fall 2020 semester, Penn State students were notified of several requirements before they would be permitted to return to campus. Students had to read and agree to COVID-19 behavioral expectations that were posted in the University's Student Information System, LionPath. These expectations included health and safety expectations such as agreeing to participate in COVID-19 testing and contact tracing, agreeing to isolate or quarantine should either become necessary under public health guidance, wearing face masks, and physically distancing themselves from others.

The University offered a variety of course modalities for the Fall 2020 semester, including remote asynchronous courses, remote synchronous courses, remote mixed-mode courses (partially online and partially in-person), and traditional in-person courses. Physical distancing and masking expectations did apply to in-person courses consistent with the students' COVID-19 behavioral expectation agreements. Regardless of course offering modality, classes were generally expected to be finished remotely after the University's Thanksgiving break. In addition to surveillance testing, over the course of the semester the University conducted 47,707 on-demand COVID-19 tests at its largest campus, with 4,666 tests returned as positive and with 427 test results not reported by the cut-off date for the Fall 2020 testing data set. The present study was conducted with students enrolled in two fully remote courses and the survey itself was distributed after the Thanksgiving break, so it can be assumed that all, or nearly all, of the respondents were in an off-campus location when they completed the survey.

The Survey

To further investigate how these circumstances influenced the way these students spent their time, the researchers developed a structured time diary format, based on the recommendations of previous researchers utilizing this format, and integrated the diary entries

into an online form, which included 9 scaled demographics questions (age, gender identity, race/ethnicity, semester standing, (intended) major, special populations, transfer status, first-generation status, and citizenship status), a descriptive question ("[w]hich of the following best describes day 1?"), one open-ended question ("[p]lease describe any/all major changes to how you spend your time now as compared to before the pandemic"), and 96 individual time slots. Students were instructed to enter a description of their activities in 30-minute intervals over the course of 48 hours, i.e. over the course of two days, of their choosing. The researchers strengthened the validity and trustworthiness of the requested items by revising the form following feedback from two student focus groups (n = 7) and an expert educational researcher. Upon approval by the institution's institutional review board (IRB), the electronic form was distributed via Qualtrics to students in November, shortly before the final examination period for the Fall 2020 semester.

Recruitment materials were sent to approximately 476 students enrolled in one (or both) of two engineering courses: a remote synchronous first-year seminar, and a hybrid remote synchronous/remote asynchronous introductory programming course for non-computer science majors; both of these courses were offered at University Park, the largest Penn State campus. Both courses were taught by the same instructor, who initiated the present study. The engineering program at Penn State is one of the highest ranked in the country, with highly competitive admission standards, and enrollment patterns that reflect a significant percentage of students from outside of the state and country (29% of overall student body in 2020).

As is characteristic of many undergraduate engineering programs, the student undergraduate engineering college population at the Penn State University Park campus overall is heavily male (77%) and traditionally aged (87.5%), a pattern that is reflected in the population of students who completed the time diaries: 67.41% of respondents (n = 242 out of 359 question respondents) reported identifying as male, and 98.6% (n = 354 out of 359 question respondents) reported being aged 18-24. Located in rural Pennsylvania, Penn State's University Park campus is a predominantly white institution (PWI), and the race/ethnicity of study participants is roughly reflective of the overall racial/ethnic composition of the institution as a whole. Participating students indicated low levels of economic insecurity (100% of respondents indicated consistent access to heat, nutrition, and dedicated workspace) or technology barriers (99% of respondents indicated consistent access to internet, hardware, and software). It should be noted that no statistically significant differences were found between genders and the demographic questions did not produce two groups of sufficient size for statistical comparison on either socio-economic status or age group.

Of the approximately 476 students who were invited to participate in the study, 363 consented to provide data for the study, yielding an effective response rate of approximately 76.1%. As is typical, however, not every student answered every question in the survey. Another 68 students (approximately 14.3% of the invited student population) accessed the survey and declined to consent to participate. This response rate is considerably higher than average for students at Penn State, especially under COVID-19 conditions, which had contributed to an observed decline in participation rates across multiple settings.

These high response rates are likely due to two primary factors. First, students were offered low-stakes extra credit for their participation, defined as opening the survey and either

consenting or not consenting to participate; this was an incentive that may have been especially salient to a student enrolled or attempting to enroll in a highly competitive major shortly before the final exam period in an especially challenging semester. It should be noted that the surveys were collected without identifying data so the instructor would not know which students had participated in the study (credit was received by providing a random number generated inside the survey). Second, students who participated in the initial focus groups (conducted for validity and trustworthiness purposes) indicated that they responded favorably to being asked to provide information in a form that generated information that was useful to them as well as the researchers. This insight is supported by previous research that suggests time diaries can be an effective reflective tool that strengthens time management skills.

Summary Findings

Students were asked to report their time diary entries in their local time zone (so, for example, if they participated in a remote synchronous class during the middle of the night their local time, it was intended that they would report it as such). Students were instructed to enter up to three activities per 30-minute time slot. Students also had the opportunity to generically note who they completed their activities with (e.g. friends, roommates, classmates, their partner, etc.), though since relatively few students provided that information those results are omitted from this study commentary. A typical time diary entry consisted of just a few words and might read as "sleeping" or "playing online games with friends."

The first day (i.e. the students' reported day 1) of time entries were manually reviewed by one coder, and entries in the diary time slots (n = 13,743 after disregarding blank entries) were hand-coded into 15 distinct activity categories that emerged from the review process: care responsibilities, class, commuting, drinking, employment, errands/chores, food, personal care, physical activity, recreation: non-screen time, recreation: screen time, sleep, socializing, studying/schoolwork, and unclear/other. A description of these codes is available in Table 1.

No code was recorded if a student omitted a time diary entry for any of the three requested activities. A second study team member then reviewed and validated the coding choices for consistency and validity. The time diary data was then processed using a combination of MATLAB computer code and Microsoft Excel spreadsheets.

For the time diaries over the day examined (the students' reported day 1), 81.40% of respondents (n = 267) noted that the day was a regular class day with class, 10.98% of respondents (n = 36) noted that the day was a regular class day without classes, 5.49% (n = 18) noted that the day was a weekend or holiday, and 2.13% of respondents (n = 7) noted that the day was some sort of other kind of day.

Over the course of the day reported, the students indicated that they engaged largely in sleep (31.11% of activities reported, n = 4,275), studying/schoolwork (19.94% of activities reported, n = 2,740), recreation: screen time (13.47% of activities report, n = 1,851), and class (8.86% of activities reported, n = 1,218). The remaining activities were scattered among the various other coding categories. The activities reported are collected via Table 2. It should be noted that because students could report multiple activities via one diary time slot, the activity

percentages do not necessary provide complete information regarding the activities' precise time allocations, but the data does provide a reasonable presentation of the activities that were occupying the students' time during the various time slots of their first reported day. Percentage activity listings distributed by time of day are provided via the Appendix. As expected, student activities peaked during daytime and evening hours, though it was clear from the data that some students were keeping "irregular hours" due to various life circumstances.

Table 1: Description of Activity Codes applied to Student Time Diaries

Activity Code	Description
Care Responsibilities	Care for those younger (e.g. siblings, cousins, etc.) or older (e.g. parents, grandparents, etc.) than themselves.
Class	Active class time, including both in-person and remote learning modalities, as well as time spent preparing for said classes.
Commuting	Traveling between activities, if its primary purpose was for commuting (e.g. walking or driving to class was coded as commuting).
Drinking	Social drinking, especially of alcohol, e.g. going to a bar.
Employment	Student reports of work or jobs that were not primarily academic in nature.
Errands/Chores	Daily living tasks, such as cleaning, laundry, or going to the bank.
Food	Consumption of food regardless of time of day or amount (e.g. breakfast, brunch, dinner, supper, snack, etc.).
Personal Care	Self-maintenance activities, including shaving, combing or brushing hair, showering, etc.
Physical Activity	Activities whose primary purpose was physical activity for its own sake, including going for a walk, working out, weight-lifting, and various sports (unless it was clear from context that they were merely watching the sport).
Recreation: Non-Screen Time	Entertainment-oriented activities such as reading, physical board games, and listening to music.
Recreation: Screen Time	Activities such as playing on one's phone; watching TV, movies, or videos; playing video games, etc.
Sleep	Activities in this category include both long-term (e.g. overnight) and short-term (i.e. naps) sleeping.
Studying/Schoolwork	Activities include academic work such as homework, studying, completing other evaluative events, experiential learning, etc., unless it was clear that the activity was part of class attendance.
Unclear/Other	If the student's intention was unclear or non-specific (e.g. simply listing a course number with no additional context), or if the student's diary entry appeared accidental (e.g. random characters were entered), the entry was coded as Unclear/Other.

Table 2. Overall Activities Reported

Activity	N	Percentage
Care Responsibilities	7	0.05%
Class	1,218	8.86%
Commuting	103	0.75%
Drinking	2	0.01%
Employment	208	2.04%
Errands/Chores	193	1.40%
Food	958	6.97%
Personal Care	880	6.40%
Physical Activity	421	3.06%
Recreation: Non-Screen Time	168	1.22%
Recreation: Screen Time	1,851	13.47%
Sleep	4,275	31.11%
Socializing	465	3.38%
Studying/Schoolwork	2,740	19.94%
Unclear/Other	182	1.32%
TOTAL	**13,743**	**100%**

Responses to the open-ended question suggest that the majority of students perceived that these averages are indicative of increased time spent on sleeping and studying and less time engaged in socializing when compared to pre-COVID conditions. This perception of change is affirmed in comparison with levels reported in pre-COVID studies of college student time spent on sleeping and studying, though this population is likely to be atypical when it comes to the latter. As one student respondent indicated, "I'm a STEM major so I expect to study a lot."

Major Student Activities

Sleep was a reoccurring theme for students, both positively and negatively. Many (n = 43) students commented on sleep in their study open-ended responses, of which a significant percentage (n = 22) commented that there has been a negative impact on their sleep. Due to omissions in student time diary entries, it is challenging to conclude precisely how many hours of sleep each day students were sleeping. However, student comments along these lines were prescient. One student observed that they "struggle to do anything productive" since they "just want to sleep all the time." Another student noted the need to take naps to rest their eyes from the strain of computer screens. However, not all views were negative; for example, one student remarked that their "sleep has gotten better as a result of not having to wake up at a certain time."

Students were aware of their increased screen time, even beyond what we coded in this study (e.g. online classes were coded as class, instead of as recreational screen time). 136 study respondents commented on their screen time in their open-ended responses, scattered across various situations such as academic (e.g. class), social, and recreational. One student commented that "[m]any days [they] often do not get a break from screens." Another student remarked that their "screen time usage has increased exponentially." In addition, one student commented on

their increased reliance on their phone: “being inside more often then [sic] ever has led [sic] me to become ever so dependent on my phone,” resulting in excessive usage.

Students spent a significant amount of time (nearly 29% percent of reviewed time diary entries) completing academic work and attending classes. Indeed, since many students suggested that their classes now offered asynchronous components, it was not always clear from student time diary entries whether students were necessarily completing lesson content delivery-related activities (class) or if they were completing assignments (studying/schoolwork). If the reported diary entries are truly representative of all students in this population, that would suggest that students are roughly averaging more than 48 hours per week of school-related activities.

While physical activity was not a leading time usage observed in the time diary, it is noteworthy because of student concerns about their decreases in physical activity. Of the 70 students who specifically commented on how their physical activity has changed, a strong majority (n = 55) noted decreases in physical activity. This is hardly surprising given student feelings of isolation as a result of the pandemic and decreased availability of organized physical activities such as recreational sports. Prior physical activity, even light walking, in some cases appears to have converted to sedentary behavior; as one student remarked, “[b]efore [the] pandemic I [was] a very active person [who] like[d] to move around,” but “since the quarantine happen[ed] I mostly or [sic] lie down all day.” Sedentary behavior over time can have significant health consequences, including an increased risk of hypertension and diabetes mellitus [20]. On the other hand, some students have been able to find opportunities to use their time to improve their physical fitness; as one student observed, “before the pandemic when classes were in person I always had difficulty finding time to work out. Now that my schedule is more flexible[,] I'm able to work out more easily[.] I work out more [now] for something to do.”

Changes in Major Activities

While the time entries provide an overall pattern of the categories of activities in which the students engaged in, the open-ended question asked them to characterize perceived changes in how they allocated their time overall. Their responses to this question (n = 359) were coded separately from the time entries, using a three-stage qualitative coding process, completed by two independent raters, and organized using MAXQDA software [21], [22], [23]. Primary activities indicated through the analysis of time entries (sleeping, exercising, class/studying, socializing) were coded either by valuation of change (negative, positive, neutral) or change in duration (more, less, neutral). For these coding items, a single rater completed initial coding of all entries, and the second rater acted as reviewer, revising codes for clarity and consistency as needed.

Emergent Themes

In addition to the structured coding items, each rater independently identified a second set of emergent codes, indicating themes not previously identified in either prior research or the diary entries. The independently derived themes were discussed with the project team and merged into a second set of four thematic codes: social responsibility, trauma-informed learning, virtual socialization, and mental health/well-being.

Social Responsibility

38 students reflected directly on their changed habits as a response that protects themselves or others in their communities. We labeled this self-reflection as social responsibility capturing the qualitative responses where students reflected directly on their changed time-management behaviors as responses to how the global COVID-19 pandemic may negatively affect others around them. Social responsibility also captured the moments when students, many of whom had returned home during the semester, had an increase of familial or household responsibility. Some students mentioned needing to watch younger children, care for aging or ailing parents and grandparents, or having to increase their workload. Many reflected on a marked decrease in party-going and in-person socializing and related this directly to their being responsible with respect to the dangers of COVID-19 communicability. Some students made stronger claims, pinpointing others, such as roommates or "the 1%" as endangering the lives and livelihoods of those around them, but particularly the students themselves.

Significantly, students who noted a lack of respect for COVID-19 restrictions by their peers or those around them had changed their own COVID-19 restrictions significantly in order to make up for their peers; for example, one student mentioned that they could not go visit family due to their roommates' socializing. As another student wrote, "the people in our area aren't taking the pandemic very seriously which has resulted in many people I care about being exposed." It is interesting that students acknowledged and reflected on how those choices directly impacted themselves and others, even without being directly asked. It may be that the social restrictions imposed by the global COVID-19 pandemic are highlighting systemic factors that affect their day-to-day lives that are typically invisible to the students themselves. On the medium range of responses, many of the students reported reducing, limiting, or even eliminating their close contact with others. As one student noted, "[t]he lifestyle has becoming [sic] monotonous, but I understand that things are the way they are for a reason, and many have it worse than I do."

Trauma-Influenced Learning

The student responses indicated that they struggled with a number of known aspects of learning under conditions of collective trauma, including focus and time management [10]. In their open-ended responses, 137 students mentioned schoolwork in some way. Many students related that they had more time for schoolwork due to the following factors: they did not need to walk or travel to class or campus, they never left their residences, and that they had fewer social engagements – if any at all. Overall, only 17 students said that their schoolwork had minimized or been aided by the pandemic while 62 said their schoolwork had increased, many using strong comparatives such as "much more" time or "many more" exams. In most cases, this increase was viewed negatively; for example, two student comments were "the effort put into class feels more intensive yet yields much worse results" and "I am still able to complete my work, but it takes much longer." These responses suggest that the additional time did not necessarily translate to more learning or an improved quality of work, which is a reflection of student struggles with time management and focus (n = 52).

Across the board, students found that not having set class times (due to recorded lectures) had upset the schedules they had become used to in their typical course work. A number of students pointed out how class attendance and study halls had shaped their usage of time and without that structure they tended to sleep more, procrastinate more, or they spent what they noted was an excessive amount of time on schoolwork. There were a few exceptions. In four cases, students noted that they were actually thriving on being able to create their own schedules, excelling in classes, or managing to find more time for exercise or self-care. The students' ability to manage their time was also interwoven with their capacities to focus under the circumstances of collective trauma. Many students noted external distractions, such as family, childcare, social media, and other such factors as being ever-present now that they often do not have separate learning and relaxing spaces. Instead of having a dedicated space for study such as the library, organized study groups, or even space away from family, students have found it more difficult to focus.

Virtual Socialization

There were interesting intersections between study time and social engagement where students noted that they spent a significant portion of their typical homework and studying time with others either in the library, study halls, or other various group settings before the COVID-19 pandemic. Many students commented that the lack of collaborative workspaces had significantly impacted their learning – even for the students who attended virtual study halls. When it came to learning, the students experienced the lack of face-to-face engagement, whether inside or outside of the classroom, as a considerable deficit. Overall, they reported marked and widespread decreases in their social activities (n = 140), but it is possible that the collective definitions of activities which "count" as socialization may be changing.

Although the students noted that they spend the majority of their time physically alone, at the same time their virtual engagement increased considerably. A significant number of students noted that they spent more time engaging with people through text message/phone (n = 39), as well as through social media, utilizing apps such as Snapchat, YouTube, Facetime, TikTok, and others (n = 35) to connect with friends and family. Unsurprisingly, many students indicated increased engagement with video games (n = 22). Perhaps more surprisingly, a number of students (n = 5) indicated that they were using video games as their primary form of virtual socialization. One student wrote, "I just play Xbox because that is the only way to talk and do stuff with my friends." Another commented that "now I can only really connect with my friends playing video games so I do that a lot more frequently now." One student did specifically note that there were limits to virtual socialization, stating that "I think that spending time with friends is a great stress-reliever that can help 'reset' yourself and prepare you for more schoolwork. Without this kind of activity (online meetings do not have the same effect), it makes it hard to be productive."

Mental Health

Throughout the open-ended responses, there was considerable evidence that students were struggling with mental health issues related to the conditions of social and physical isolation, general anxiety over the state of the world, and disruptions in how they spent their

time. The qualitative coding for anxiety and depression was conducted based on the characteristics of anxiety and depression disorders in the Diagnostic and Statistical Manual of Psychological Disorders, 5th Edition (DSM-5) [24]. Students who reported expressing a loss of interest, pleasure, and energy; depressive moods; helplessness; and hopelessness were coded with depression. On the other hand, descriptions of tensed feelings, intense fear, rumination of anxiety, worries, restless, and anxiety were coded as anxiety. Based on these markers, 24 responses were coded as having significant markers for depression. In several notable cases, these responses were simply heartbreaking, giving context to the extent of mental health concerns that are often expressed merely as statistics. Sample student statements along these lines include the following: "I don't enjoy anything, I lost my happiness, and my will to work and live;" "I don't find joy in the things that used to make me happy;" "I am much more lonely now during the pandemic;" and that they were "more sad pondering during the day instead of being with people and active doing beneficial things for my life."

In many other cases, students indicated symptoms that could be signs of depression (e.g. "I've been sleeping more") but for which the coders lacked sufficient context to label the behavior with confidence. Potential signs of concern for the well-being of these students was evident throughout all of their responses, but overall, these tended towards signs of depression. The student response gave minimal indication of anxiety (n = 7), either directly or indirectly, a statistic that is somewhat surprising, as previous research has indicated that anxiety levels tend to rise around major examination periods such as finals exam [25] (around which point in the semester when the time diaries study was administered). Due to COVID-19 conditions, Penn State had allowed for alternative grading options during the Fall 2020 semester, which may account for some of the lower-than-expected indicators of anxiety, but comparatively few students in the engineering program availed themselves of these options and there were no indicators of this policy in their open-ended responses.

Study Limitations

The findings of this qualitative study are suggestive. Though the response rate is notably high, the results only encompass relatively privileged students enrolled in undergraduate engineering majors at a single institution under exceptional global circumstances. While there is reason to believe that the student responses constitute more authentic evidence than conventional survey items, there is also reason to believe that students engaged in some selective self-editing when reporting their activities. For example, it seems unlikely that, out of 363 largely traditionally aged college students, not a single student either co-slept with anyone else or had engaged in any sexual activities over the course of a day, but there were no reports of these activities in any of the time diaries we had reviewed. Similarly, it seems likely that alcohol and recreational drug use, while not entirely absent (three specific mentions appear in the open-ended responses), were under-reported. The survey instructions did indicate that students were not compelled to report activities that they preferred to keep private, but the extent to which the students implemented privacy filters on their reported activities is unknown.

The study was conducted at a single university, and one that is admittedly privileged in many respects. For example, the respondents indicated few if any issues of economic insecurity or technology access. Nor were the respondents likely to be academically precarious. The

stringent standards for continued enrollment in the engineering program might have put some students at risk for being asked to leave the program, but even in those cases, the student would typically not be close to flunking out of college. These conditions of privilege are likely to have had a significant effect on how these students chose to spend their time, as evinced by emerging studies of the disproportionate effects of quarantine and other COVID-related conditions on women, adult students, LGBTQA+ students, and members of under-served populations [26], all of which were under-represented in the population sampled in this study. Our results do suggest, however, that it may be illuminating to conduct similar time diary studies at other institutions and across more diverse student populations.

Possible Mental Health Interventions

The time diaries indicate that the students did not fundamentally change the categories of activity (e.g. sleep, studying) but that they did shift the relative weight of each of these activities largely in response to major changes in global and instructional contexts. While there are multiple implications to be gleaned from these shifts in activity, perhaps the most pressing call to action is to address the serious challenges to mental health. The significant number and intensity of students reporting depressive symptoms raises the need of timely and effective intervention before further worsening of student mental health. The literature on college student mental health recommends a number of institutional-level prevention strategies ranging from ongoing psychoeducational prevention programming to early screening and referral to campus mental health services, and initiatives to foster opportunities for socio-emotional connections with peers, staff, and/or faculty, often in the form of networks of care [27], [28], [29], [30].

At the level of instruction, educational research underscores the effectiveness of relatively short (5-10 minute) interventions that serve to briefly exemplify, demonstrate, and model emotional coping skills, such as mindfulness practice, consistent sleep and exercise schedules, virtual socialization with peers, and resilience [31], [32], [33], [34]. Further studies suggest that periodic check-ins with students improves motivation, persistence, and well-being. It should be noted that mental health issues such as depression and anxiety were rising among college students even prior to the outbreak of the pandemic [35], but these extraordinary conditions may serve to heighten our awareness of them and to normalize pedagogies of care that can be maintained even after the crisis recedes [36].

It is difficult to read some of these responses and not wish to help these students, so it is tempting to provide longer lists of specific mental health interventions that had proven to be effective prior to the COVID-19 pandemic. However, the researchers wish to sound a note of caution before one jumps to implement such interventions. Because the evidence base for many of these practices was developed under very different conditions than the students are currently facing, their efficacy in these circumstances remains largely unknown and should, therefore, best be left to trained professionals. Our findings do suggest that the solution at hand may be simpler than this. This study was conducted primarily to provide deeper insight into students' mental worlds, which, in turn, should serve as the basis of teaching and learning practices that are, above all else, compassionate in their execution and intention.

Possible Time Optimization Interventions

Our findings suggest that students are facing an optimization problem, a framing with which engineers are often familiar, when it comes to how they are utilizing their time. Many students indicated that they did not feel as if they were spending their time as productively – whether inside or outside of the classroom – as they would like to. As one student put it, "now I feel as though I have more free time but less to fill it with." Furthermore, our findings suggest that students have increased their engagement in activities such as recreational gaming and social media usage, both of which have been shown to have negative correlations with academic success and well-being [37]. This begs the question of what can be done to help students to better optimize their time, especially in the absence of conventional markers, such as face-to-face class times.

After reviewing the literature, Miertschin et. al [38] concluded that evidence was mixed as to the extent that time management could be taught, but that there were some indicators that it can be modelled and coached. The preference may be for faculty to do this coaching. They are, after all, the experts on student learning in their courses. Certainly, instructors should not hesitate to offer advice to students who express concerns about their ability to manage their own time. The inspiration for this study actually came from a time management intervention, previously implemented in one of the two courses covered by the current study, in which students recorded their activities in a time diary and were then asked to reflect on how they might better manage their time. That said, additional research suggests that faculty themselves may be struggling with the burden of emotional labor and may not have fully optimized their own time usage under the conditions of "pandemic pedagogy."

Implications for Future Research

This study indicates changes in how college students spend their time and, by extension, the effect of these activity shifts on their perceptions of learning and overall well-being. As such, it serves to extend pre-existing research questions on time utilization and apply these to the changed context of remote/multi-modal learning in the 2020-21 academic year. The student responses, especially to the open-ended questions, also provide glimpses of new potential questions future researchers may be able to explore regarding the dimension of time in higher education. Taken as a whole, the responses of these students are suggestive of deeper shifts not just in how they spend their time, but in how they perceive temporality, i.e. their relationship with time. This insight dovetails with recent work regarding the changing temporality of "fourth spaces," i.e. virtual places, such as the ubiquitous video conferencing rooms or virtual gaming spaces, in which the conventional distinctions between home, work, and community life are collapsed [39], [40], [41]. In these spaces, time is no longer limited by conventional boundaries, and emerging studies, including to some extent the present one, suggest that when immersed in these fourth places, our perception of time may take on qualities of greater elasticity, ambiguity, and complexity [42].

Higher education scholars, too, have expressed emerging concerns about the potential implications of radical shifts in temporality that may arise as long-term consequences of the COVID-19 experience. This is especially salient in the weakening of future orientation, which

has been shown not only to influence mental health, but which also constitutes a significant challenge to the foundation of many instructional, curricular, and co-curricular models currently prevalent at most universities [43], [44], [45], [46]. How might one design and teach a course, for example, to prepare students for a future about which so little is known that we are unable to articulate either a set of required knowledge or requisite skills [47], [48], [49]? Rather than view such a prospect as daunting, the question is how we, as researchers and educators in higher education, can rise to the occasion and work with our students to become co-creators of a post-COVID-19 future that is not as much unknown as not yet realized. Rather than endeavoring to build a time machine, perhaps we could strive to equip a generation of intrepid time travelers.

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Appendix

The tables that follow depict the activities reported as a percentage of student activity for various times of day for the examined study day (day 1).

Table A1: Activities Reported as a Percentage of Activity from 0:00 to 2:30

ACTIVITY	0:00	0:30	1:00	1:30	2:00	2:30
Care Responsibilities	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Class	2.72%	2.61%	2.24%	2.27%	2.73%	1.98%
Commuting	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	0.68%	0.75%	0.37%	0.76%	0.78%	0.79%
Errands	0.34%	0.37%	0.75%	0.76%	0.78%	0.40%
Food	0.68%	0.37%	1.12%	0.38%	0.78%	0.40%
Personal Care	3.74%	2.61%	2.99%	0.76%	1.56%	1.19%
Physical Activity	0.34%	0.37%	0.00%	0.38%	0.39%	0.40%
Recreation: Non-Screen Time	1.02%	0.37%	0.37%	0.76%	0.78%	0.00%
Recreation: Screen Time	22.79%	20.15%	17.54%	12.12%	5.47%	2.78%
Sleep	50.68%	58.21%	64.93%	73.86%	81.64%	87.30%
Socializing	3.40%	2.61%	1.12%	1.14%	1.17%	1.19%
Studying/Schoolwork	12.93%	10.07%	7.09%	5.68%	2.34%	2.38%
Unclear/Other	0.68%	1.49%	1.49%	1.14%	1.56%	1.19%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A2: Activities Reported as a Percentage of Activity from 3:00 to 5:30

ACTIVITY	3:00	3:30	4:00	4:30	5:00	5:30
Care Responsibilities	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Class	0.81%	0.41%	0.40%	0.41%	0.41%	0.00%
Commuting	0.00%	0.41%	0.40%	0.00%	0.00%	0.40%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	0.81%	0.82%	0.80%	0.82%	0.41%	0.40%
Errands	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%
Food	0.81%	0.41%	0.00%	0.41%	0.82%	0.81%
Personal Care	0.81%	0.00%	1.20%	0.41%	0.41%	1.21%
Physical Activity	0.00%	0.00%	0.40%	0.00%	0.41%	0.81%
Recreation: Non-Screen Time	0.00%	0.00%	0.40%	0.41%	0.00%	0.00%
Recreation: Screen Time	2.43%	2.45%	1.61%	1.23%	0.82%	1.62%
Sleep	91.09%	92.65%	90.76%	92.59%	93.03%	91.09%
Socializing	0.40%	0.41%	0.00%	0.00%	0.00%	0.00%
Studying/Schoolwork	1.62%	1.63%	2.81%	2.47%	2.05%	2.02%
Unclear/Other	0.81%	0.82%	1.20%	1.23%	1.64%	1.62%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A3: Activities Reported as a Percentage of Activity from 6:00 to 8:30

ACTIVITY	6:00	6:30	7:00	7:30	8:00	8:30
Care Responsibilities	0.00%	0.40%	0.00%	0.00%	0.00%	0.34%
Class	0.39%	0.40%	1.19%	2.73%	9.72%	9.43%
Commuting	0.39%	0.40%	1.19%	0.39%	1.39%	1.01%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	0.79%	1.20%	0.79%	1.56%	1.74%	2.02%
Errands	0.39%	0.00%	0.40%	1.17%	1.04%	1.01%
Food	3.15%	2.81%	3.56%	3.91%	7.29%	10.10%
Personal Care	2.36%	1.61%	6.32%	5.47%	10.76%	17.17%
Physical Activity	0.39%	1.61%	1.19%	1.95%	3.13%	3.37%
Recreation: Non-Screen Time	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Recreation: Screen Time	1.97%	2.41%	1.58%	2.73%	2.08%	6.40%
Sleep	87.01%	87.15%	81.42%	76.56%	56.60%	43.10%
Socializing	0.39%	0.00%	0.00%	0.00%	0.35%	0.67%
Studying/Schoolwork	1.18%	0.80%	1.58%	3.13%	5.21%	4.04%
Unclear/Other	1.57%	1.20%	0.79%	0.39%	0.69%	1.35%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A4: Activities Reported as a Percentage of Activity from 9:00 to 11:30

ACTIVITY	9:00	9:30	10:00	10:30	11:00	11:30
Care Responsibilities	0.00%	0.00%	0.00%	0.00%	0.00%	0.35%
Class	26.01%	27.12%	23.34%	25.57%	26.62%	26.04%
Commuting	1.35%	0.68%	1.26%	0.97%	0.00%	1.04%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	2.36%	2.37%	2.52%	2.91%	1.62%	2.08%
Errands	1.01%	1.69%	3.15%	1.29%	1.30%	2.43%
Food	9.46%	6.44%	11.36%	9.39%	10.71%	12.85%
Personal Care	9.46%	11.19%	13.25%	10.36%	9.09%	5.90%
Physical Activity	2.70%	2.71%	2.84%	3.88%	4.87%	3.82%
Recreation: Non-Screen Time	0.68%	1.02%	1.26%	0.97%	0.32%	1.74%
Recreation: Screen Time	3.38%	5.42%	8.20%	8.74%	9.74%	9.38%
Sleep	31.08%	25.42%	17.03%	11.97%	7.79%	6.94%
Socializing	0.68%	2.37%	1.89%	1.62%	1.95%	1.04%
Studying/Schoolwork	8.78%	11.86%	12.30%	20.06%	23.70%	25.00%
Unclear/Other	3.04%	1.69%	1.58%	2.27%	2.27%	1.39%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A5: Activities Reported as a Percentage of Activity from 12:00 to 14:30

ACTIVITY	12:00	12:30	13:00	13:30	14:00	14:30
Care Responsibilities	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Class	21.58%	24.76%	19.46%	17.11%	15.82%	16.89%
Commuting	1.22%	0.63%	0.30%	0.00%	1.35%	0.68%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	1.22%	1.57%	2.40%	3.95%	5.05%	3.72%
Errands	1.52%	1.88%	3.29%	1.64%	2.02%	2.36%
Food	18.24%	11.91%	13.47%	12.17%	7.41%	5.41%
Personal Care	8.81%	8.46%	6.29%	4.61%	5.72%	6.42%
Physical Activity	4.26%	4.08%	4.19%	6.58%	8.75%	7.09%
Recreation: Non-Screen Time	0.61%	1.88%	0.60%	1.32%	1.01%	2.03%
Recreation: Screen Time	12.16%	15.67%	14.67%	14.80%	9.43%	10.47%
Sleep	4.26%	3.76%	3.59%	3.95%	4.71%	4.05%
Socializing	2.13%	2.19%	3.29%	2.96%	2.36%	1.01%
Studying/Schoolwork	22.80%	21.32%	26.35%	29.28%	35.69%	38.85%
Unclear/Other	1.22%	1.88%	2.10%	1.64%	0.67%	1.01%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A6: Activities Reported as a Percentage of Activity from 15:00 to 17:30

ACTIVITY	15:00	15:30	16:00	16:30	17:00	17:30
Care Responsibilities	0.00%	0.34%	0.00%	0.34%	0.31%	0.00%
Class	18.47%	14.19%	13.51%	8.53%	6.54%	3.46%
Commuting	1.05%	2.03%	0.68%	2.39%	2.49%	1.57%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	3.83%	3.04%	4.39%	3.75%	2.80%	2.20%
Errands	1.74%	1.35%	2.03%	2.05%	4.05%	2.52%
Food	2.79%	5.07%	4.05%	3.75%	13.40%	19.50%
Personal Care	6.27%	6.08%	6.76%	9.90%	11.53%	10.38%
Physical Activity	8.01%	6.76%	7.77%	7.85%	7.48%	5.66%
Recreation: Non-Screen Time	1.39%	2.03%	3.04%	2.39%	1.87%	2.52%
Recreation: Screen Time	10.10%	15.20%	11.82%	11.26%	11.84%	12.26%
Sleep	3.83%	1.69%	2.36%	3.07%	2.49%	2.52%
Socializing	1.39%	3.38%	4.05%	5.80%	4.36%	5.03%
Studying/Schoolwork	38.68%	37.16%	38.18%	37.88%	30.53%	31.45%
Unclear/Other	2.44%	1.69%	1.35%	1.02%	0.31%	0.94%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A7: Activities Reported as a Percentage of Activity from 18:00 to 20:30

ACTIVITY	18:00	18:30	19:00	19:30	20:00	20:30
Care Responsibilities	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%
Class	3.30%	2.30%	2.61%	1.36%	2.32%	2.36%
Commuting	1.65%	0.66%	1.63%	1.02%	0.66%	1.35%
Drinking	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Employment	3.30%	3.61%	3.27%	3.40%	2.98%	2.03%
Errands	3.63%	3.61%	1.63%	1.36%	0.99%	1.01%
Food	24.42%	22.62%	14.71%	9.86%	9.27%	5.41%
Personal Care	7.59%	5.57%	7.84%	6.12%	4.64%	6.42%
Physical Activity	4.29%	3.61%	2.94%	3.40%	2.98%	2.03%
Recreation: Non-Screen Time	1.65%	1.64%	1.96%	2.38%	2.32%	3.04%
Recreation: Screen Time	15.84%	19.02%	19.61%	22.11%	23.84%	25.34%
Sleep	0.99%	0.33%	0.65%	0.34%	0.33%	1.01%
Socializing	4.95%	6.56%	7.84%	7.82%	11.59%	11.15%
Studying/Schoolwork	27.39%	29.84%	34.31%	38.44%	36.09%	37.50%
Unclear/Other	0.66%	0.66%	0.98%	2.38%	1.99%	1.35%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table A8: Activities Reported as a Percentage of Activity from 21:00 to 23:30

ACTIVITY	21:00	21:30	22:00	22:30	23:00	23:30
Care Responsibilities	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Class	2.35%	2.33%	1.99%	1.79%	2.78%	2.05%
Commuting	0.34%	0.00%	0.66%	0.71%	0.35%	0.00%
Drinking	0.00%	0.33%	0.33%	0.00%	0.00%	0.00%
Employment	2.35%	1.66%	1.99%	1.07%	0.69%	0.34%
Errands	0.34%	1.33%	1.33%	1.79%	1.39%	0.68%
Food	3.36%	3.99%	2.33%	1.43%	2.43%	1.03%
Personal Care	6.71%	8.97%	7.97%	7.50%	7.64%	7.53%
Physical Activity	1.68%	1.66%	1.33%	0.71%	1.04%	0.34%
Recreation: Non-Screen Time	1.68%	1.99%	2.33%	1.79%	2.43%	2.40%
Recreation: Screen Time	31.88%	34.22%	36.54%	36.79%	32.29%	26.71%
Sleep	2.01%	4.65%	8.31%	12.50%	21.88%	36.30%
Socializing	10.07%	8.64%	9.30%	6.79%	6.25%	4.45%
Studying/Schoolwork	35.91%	28.90%	24.92%	26.07%	20.14%	17.47%
Unclear/Other	1.34%	1.33%	0.66%	1.07%	0.69%	0.68%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**