Pandemic Software Development: The Student Experience

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***Abstract*—The COVID-19 pandemic has birthed a wealth of information through many publicly accessible sources, such as news outlets and social media. However, gathering and understanding the content can be difficult due to inaccuracies or inconsistencies between the different sources. To alleviate this challenge in Australia, a team of 48 volunteering students developed a COVID-19 information dashboard (covid-19-au.com) to provide accurate, reliable, and real-time COVID-19 information for Australians whilst working under legislative restrictions that required social isolation. The COVID-19 information dashboard has been playing a decisive role in keeping the Australian community informed during the COVID-19 pandemic. We conducted an online survey to characterize the experiences of the students throughout the project. Our results indicate that playing a positive role in the COVID-19 crisis, and learning new skills and technologies were the most cited motivating factors for the students to participate in the project. While working on the project, some students struggled to maintain a work-life balance due to working from home. The students expressed more strongly that data collection was a significant challenge as it was difficult to collect reliable, accurate, and up-to-date data from the various government sources. The students have been able to mitigate these challenges by establishing a systematic data collection process in the team, leveraging frequent and clear communication through text, and appreciating and encouraging each other's efforts. By participating in the project, the students boosted their technical (e.g., front-end development) and non-technical (e.g., task prioritisation) skills. Finally, our study discusses several implications for students, educators, and policymakers.**

***Index Terms*—COVID-19, Pandemic, Student, Software Engineering Education, Software Development**

I. INTRODUCTION

The emergence and spread of the coronavirus disease 2019 (COVID-19) has had a global impact, with 189 countries having reported cases as of October 17, 2020 [1]. In Australia, federal restrictions were enacted to reduce community transmissions, which have resulted in the closure of work premises and university campuses. Consequently, work and collaboration have needed to shift into remote and online environments.

The distribution and reporting on the various aspects of COVID-19 through multiple sources, such as federal reports or social media, has posed a challenge for Australians in understanding the numerous facets of the pandemic situation. In light of this, a team of 48 student volunteers has developed the COVID-19-AU information dashboard (covid-19-au.com) whilst working under legislative restrictions that required social isolation. The project is a data aggregation software that aims to ease the challenge of understanding COVID-19 in Australia by providing reliable, accurate and updated information about the pandemic. The site displays a variety of useful metrics, data visualizations and relevant articles derived from the various information sources.

Prior research on developing COVID-19 software has concentrated on technical challenges like bugs and improving software quality [2]. Studies related to working during a pandemic also focus on the consequences of relocating into a new working environment with working from home [3]. These works investigate the problems, motivations and experiences of practicing professionals in an organizational setting, however, no previous research inspect these elements from the perspective of a student team developing a software project during the COVID-19 pandemic. The challenges faced by a student team may vary from that of a professional team due to various factors like lack of prior work experience or the absence of pre-existing policies to aid work management during a crisis. Consequently, these differences may also display varying behaviour in how the students adapt and overcome these challenges.

The research presented in this paper aims to identify and comprehend the experiences of the students that contributed to the COVID-19-AU information dashboard project in four areas: their motivations to contribute to the project, the challenges while working on this project, the strategies employed to overcome the challenges, and the learning's gained through the experiences. To this end, we conducted an online survey with the participating students, with questions formulated based on a pilot analysis of the team's internal messages on Slack and their usage of GitHub and existing literature.

Our findings indicate that playing a positive role in the crisis was the motivation most selected by the participants. Other significant motivations included learning new skills and technologies and gaining experience for their CV. The most prominent challenges for the students were regarding data collection, which was strongly attributed to the unreliability and inaccuracy of the data provided through government sources. More generally, the students also expressed difficulty in maintaining a work-life balance while working from home

and in forming relationships with the other contributors as the project's development was entirely online. As mitigation strategies to these challenges, the students most frequently used clear language when messaging other team members. Team morale was also maintained through vocal appreciation of the work and by encouraging the other contributors. Overall, the students exhibited a growth in their technical and non-technical skills, particularly in their front-end development skills, understanding of COVID-19 and ability to work online.

Our work makes the following contributions:

- A better understating of the student experience in pandemic software development.
- Practical implications for students, researchers, and policymakers.

Paper Organisation: Section II provides the background. In Section III, we explain our research method. Section IV reports the findings. We reflect on our findings in Section V. Section VI summarises the related work. Finally, Section VII concludes our study.

II. Background

A. COVID-19

COVID-19 is an infectious disease that has resulted in a global pandemic [4]. As of September 3, 2020, there have been 25,884,895 confirmed cases of COVID-19 and 859,130 confirmed deaths [5]. The pandemic has severely impacted the lives of many vulnerable communities, affecting both physical and mental health. Studies have shown that there has been a sharp drop in life satisfaction amongst people around the world, including Australians, and an increase in psychological distress levels [6].

Like other countries, the Australian government introduced legislative restrictions to minimise the spread of the disease [7]. These restrictions included limiting public gatherings, shutting down on-site working alongside encouraging working from home (WFH), and limiting the reasons for leaving the house. In regions with a higher number of cases, such as Melbourne, further restrictions were implemented, for example, placing a 5km radius restriction on an individual travelling from their house or a mandatory curfew by which individuals must return home. Additionally, these restrictions resulted in the closure of Australian university campuses, with students and staff needing to transition into an online environment [8].

B. COVID-19 Information Dashboard

Through the progression of this pandemic, a plethora of information about the disease has become publicly available through many different sources, such as news outlets, federal and state reports, and social media [9]. The consolidation of these sources can be overwhelming due to inaccuracies or inconsistencies between their content.

In response to this challenge, the COVID-19 information dashboard was developed as a data aggregation software for COVID-19 information. The website aims to help Australians stay informed on key areas of the disease, such as case numbers, outbreak hot spots and relevant news articles. Fig. 1 is a snippet of the information dashboard.

1) Contributors: The COVID-19 information dashboard project is an open source software (OSS) that is maintained and managed by a team of 48 volunteers, largely comprising of university students. These students were recruited primarily through advertisements on student social spaces and by word of mouth. The team includes several key areas: data collection, data visualization, web development, and marketing. Many of the participants did not have prior expertise in relation to their area of contribution. The majority of participants also had no prior professional experience in working on a software project. A further breakdown of the team's demographics is presented in Section IV-A.

2) Features: The COVID-19 information dashboard displays a variety of metrics on COVID-19. The confirmed cases, active cases, recovered cases, test numbers, hospital numbers, and deaths are presented both numerically and through heat map visualizations. The specificity of the data can also be varied between a national view, state view, and local government area view. In addition, time series data visualizations are also available to view historical figures or trends in the data. Other key features of the website also include a global comparison of COVID-19 between Australia and other nations, demographic analysis of the pandemic by state, and a timeline of COVID-19 related news articles released by reputable outlets. The data used by the site is updated in real time through the use of an automated data crawler that scrapes various sources, such as government reports, news articles, and social media posts. The data also undergoes a manual review to manage inconsistencies or mistakes.

3) Development Process: Due to the restrictions in Australia, the team was required to collaborate through a purely online medium, with many also having to contribute while working from home. Communication within the team was largely facilitated through the use of Slack, which provides private messaging, channel messaging, and video conferencing services. In addition, GitHub was used as the version control hosting site for the software. The developers would perform issue labelling and provide feedback through the features provided by the platform.

In addition, the team had to self-manage and develop the necessary policies and processes for project development. This included the on-boarding process of new members, managing shared resources such as spreadsheets and code, and the workflows required to ensure ongoing tasks could be tracked. Several of the strategies adopted by the team in developing the software are discussed in this paper.

4) Project Impact: The project has gathered much public attention, with the website achieving approximately 10.5 million visits as of October 15, 2020. Among all the visitors, more than 200,000 (22.2%) users are returning users. It has attracted over 700,000 unique users since its release and had almost 60,000 users access the site in a single day during the peak of the pandemic in Australia. Although most users are from Australia, the site has attracted visitors from 180

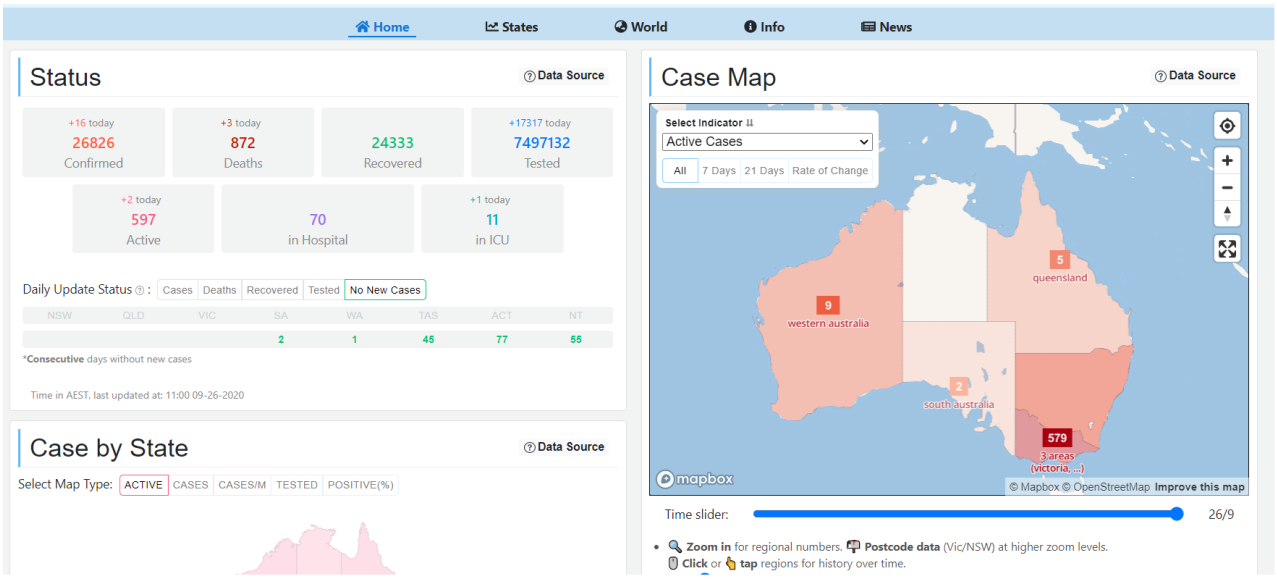

Fig. 1. COVID-19-au.com Dashboard

other countries around the world. There have been 3,641,690 sessions, with users spending 2.62 minutes on average in each session.

User feedback collected through different channels (e.g. social media, email, online survey) showed that around 81% of the users feel had positive reviews of the website. Examples of positive user sentiments include *"it is so impressive to see the additional features that seem to be added daily"* and *"I check every day for updates. I've shared with many friends and family and we all think you've done an amazing job"*. Feature requests from users was also used in developing features on the site.

III. Research Method

To characterise the experiences of the student volunteers of the COVID-19 information dashboard project (for brevity, we refer to it as the COVID-19 project) during the COVID-19 pandemic, we conducted a survey. We obtained ethical approval from our university before distributing the survey.

A. Research Questions

Our study was guided by the following research questions:
RQ1. *What factors motivated students to contribute to the COVID-19 project during the COVID-19 pandemic?*

Motivation: Students may have participated in the COVID-19 project for different reasons, such as improving their CVs and challenging themselves. This question aims to understand what factors motivated students to work on the COVID-19 project during the COVID-19 pandemic.

RQ2. *What challenges do students experience when working on a COVID-19 project during the COVID-19 pandemic?*

Motivation: Software development is a collaborative and joint endeavour that involves individuals with diverse skills and seniority. The COVID-19 pandemic may negatively influence this process. For example, participating students may have had a lack of or inadequate access to (accurate) resources (e.g., data). They may have faced new or exacerbated software bugs that they did not experience before [2]. Hence, we aim to provide a comprehensive understanding of such challenges that may have impacted students' learning process and work on the COVID-19 project.

RQ3. *What strategies do students employ when working on a COVID-19 project during the COVID-19 pandemic?*

Motivation: This question aims to gain an in-depth understanding of the strategies and practices that students consider beneficial in minimising the impact of the COVID-19 pandemic on the project and their involvement in the project.

RQ4. *What skills do students learn when working on a COVID-19 project during the COVID-19 pandemic?*

Motivation: Participating students may have learned and developed new technical and non-technical skills and expertise while working on the project within the COVID-19 pandemic. Such skills and experiences may be leveraged by students and their peers in the future to deal with such kind of crises and disasters in their personal life or professional career.

B. Pilot Study

Research on the effects of the COVID-19 pandemic on software development and software engineering education is rare. Hence, it was challenging for us to design appropriate and comprehensive survey questions. To better understand the possible challenges faced by and solutions adopted by students, we conducted a pilot study before the survey to analyse the team discussions on Slack and the issue tracking system of the project.

Slack. First, the text dump of messages was cleaned, and non-text blocks such as links and code snippets were removed.

TABLE I
TOP 10 CHALLENGES HIGHLIGHTED BY SLACK MESSAGES

Code	Total
Collecting data	147
Designing the interface	57
Working with the codebase	57
Having the necessary experience for the project	29
Time management with project tasks	29
Mistakes in day entry	22
Online communication	15
Heavy workload	11
Using internal team resources	11
Balancing external commitments	9

Next, the text was tokenised, and the tokens were categorised by research question. The tokens were then used as search terms for relevant messages, with further filtering done to remove false positives. Finally, the relevant messages were open coded into categories that would form the basis of our survey questions. For instance, the challenge of *collecting data* made up a high proportion of challenge-related messages (147 out of 457, or 32.17%), as shown in Table I. This informed several data collection specific challenges that were presented in a separate section of the survey. Additionally, we also observed a substantial proportion of messages centred around proactive collaboration, such as offering to help with debugging or acknowledging team members' work. As a result, *actively responding to teammates' messages* and *encouraging the efforts of other members* were included as strategy statements in the survey.

Github. We also analysed comments in pull requests and raised issues to identify common topics of discussion raised by the participants. Of 66 discussion threads, the majority of conversations centred around *bug fixes* and *code review*, further reinforcing the Slack data analysis that showed participants lacked technical experience and working with the codebase. Another discussion details how participants worked together to establish a reliable source for the number of recovered cases to replace the Australian government website when it stopped releasing them in late March. This resulted in providing the basis for the strategy prompt *discussing any differences found across data sources with my team* to be included in the survey.

C. Main Study: Survey

1) Protocol: We designed an online survey[1] with 27 questions using Qualtrics software[2], which took approximately 25 minutes to complete. Of 27 questions, 17 questions were closed-ended questions, and the rest were open-ended. The survey questions were mainly formulated based on the existing literature [3], [10], [11] and our pilot study (i.e., analyzing the students' discussions on Slack and GitHub). The survey started with a brief overview of our research objective. The survey questions can be generally organised into 5 groups:

Demographics. Our survey had 10 questions to collect demographic information such as students' gender, their role in the project, and their prior professional experience in software development.

Motivations. Inspired by [11], we designed a multiple-choice question to seek the motivations of the students to contribute to the project.

Challenges. We used 13 statements (i.e., some of them adopted from [3], [10]) to measure to what extent students agreed or disagreed with the potential challenges (if any) that may have occurred during their work on the COVID-19 project. The statements were rated based on a six-point Likert scale (from "Strongly agree" to "Strongly disagree"). It is worth noting that we also provided "Not Applicable" in the answer options, which allowed students to indicate if they did not face a given challenge. We also designed 4 six-point Likert scale statements to seek the level of agreement or disagreement of students on the possible challenges in data collection during the project.

Practices. Similarly to the challenges, we designed two types of statements to explore how often students applied a provided list of 10 practices or techniques to address the challenges they encountered during the project, as well as 5 used exclusively during the data collection. The students were asked to rate them using five-point Likert scale statements (from "Very often" to "Never").

Skills. The students were asked to show how confident they were about 8 soft skills and 8 technical skills before contributing to the COVID-19 project and after participating in the project. These statements were rated on eleven scales from 0 (not confident) to 10 (very confident).

It should be noted that all multiple- and single-choices questions were followed by an open-ended question to collect further opinions and thoughts from the students.

2) Participants: The survey participants were recruited from the volunteering students who contributed to the COVID-19 information dashboard. In total, 48 students were involved in different steps of the project. After collecting the email addresses of the 48 students, we sent an invitation email to all of them. We also sent a message via Slack and invited them to fill in the survey. To encourage students to complete the survey, we promised the students that they would receive an incentive of an 80 AUD Coles gift card for participating. Finally, we received 39 responses (acceptance rate: 81.25%)

D. Data Analysis

Closed-ended questions were analysed using descriptive statistics, while open-ended questions were analysed using open coding [12] and axial coding [13]. The codes generated were used to provide more descriptive results for the related closed questions.

[1]https://bit.ly/346MMcV

[2]https://www.qualtrics.com/au/core-xm/survey-software/

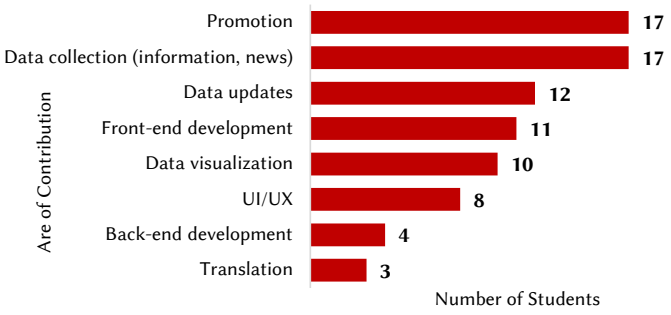

Fig. 2. Breakdown of COVID-19-AU team by area of contribution

IV. Findings

A. Demographics

Age. The participants' ages ranged from 20 years old to 35 years old. The mean age of the participants is 24.56 years.

Gender. Of 39 participants, 27 (69.23%) were male, and the rest (12, 30.77%) were female.

Education Level. 51.28% of the participants stated that they completed a postgraduate degree, and 43.59% indicated that they completed an undergraduate degree. The remaining 5.13% indicated high school or equivalent as their highest level of education.

Role. 35.90% of the students indicated that they mainly contributed to the project as a developer. 12 students (30.77%) mentioned that their primary responsibility was marketing. Information contributor was another highly cited role by the students (23.08%).

Area of Contribution. Fig. 2 depicts the different aspects of the project and the proportion of survey participants identified as having worked in each area. A single team member could select multiple areas. The most dominant areas of the project were data collection (17, 43.59%) and promotion/marketing (17, 43.59%).

Experience. 29 students (74.36%) pointed out that they had no experience in software development in the industry before joining the project. Only 10 students (25.64%) indicated that they had such experience: 4 had 1-2 years experience, 5 had 3-5 years experience, and 1 had more than 10 years experience.

B. RQ1: Motivating Factors

The participants were presented with 12 motivations and asked to select the statements that applied to them. Table II shows the motivations that the participants selected from.

Given the ongoing pandemic, 89.74% of participants were highly motivated to play a positive role in the crisis. 58.97% took the project as an opportunity to demonstrate their skills, with one participant commenting he could use his past experience in *"projects (that...) involved large-scale data collection and normalization"* to contribute *"towards Australian and international efforts combating this pandemic"*. 61.54% wanted to learn more about COVID-19, and close to 48.72% also saw this as an opportunity to experience working on a crisis related software project.

As mentioned earlier, 74% of the students had no software development experience in industry before joining the project, which may have resulted in the team being strongly motivated by the desire to learn new skills and technologies (77%), and gaining experience for their CV (69%). Moreover, participants further expressed they wanted to build a network by meeting and communicating with new people (67%) and to contribute in a student initiated/led project (64%). Other notable motivations of the students included undertaking tasks that would challenge their technical skills (49%) and learning how a real software system is developed in industry (44%). Participants largely disagreed with participating simply to occupy free time, with only 26% agreeing with statement M10.

> **RQ1 Summary.** *We found that playing a positive role in the COVID-19 crisis, learning new skills and technologies, and gaining experience for their CV were the most cited motivations for volunteering students to contribute to the COVID-19 information dashboard. Students were not motivated to participate as a means to occupy free time.*

C. RQ2: Challenges

We classify the possible challenges that the students faced into two groups: General Challenges and Data Collection Challenges.

1) General Challenges: We presented the survey participants with a list of possible challenges, which is shown in Table III. Generally speaking, none of the challenges were agreed by more than 50% of the participants. Approximately 40% of students considered balancing their commitments to be a challenge (statement C1). Given that the COVID-19 information dashboard was open source, and the team consisted primarily of students, the contributors would have needed to balance their commitments between this project and university.

Mental health is also an area of concern during the pandemic, as Bibble et al. report that psychological distress levels have increased during the pandemic period [6]. However, our participants did not feel that it was challenging for them to manage their mental and physical health when working on this project during the pandemic (statements C2 and C3 receptively), as over 80% disagreed with these statements.

The contributors to the project were required to work from home as per the government restrictions in Australia. Approximately 50% of participants agreed that establishing a work-life balance while working from home was a challenge (statement C6). Subsequently, 34% responded that it was challenging to manage distractions while working from home (statement C5), and 31% found it difficult to stay motivated while working from home (statement C8).

While the vast majority of the participants (86.84%) did not agree that working only through an online medium was a challenge (statement C10), 29% of them felt that it was difficult to collaborate through a purely online medium (statement

TABLE II
LIST OF MOTIVATING FACTORS AND SURVEY RESPONSES

ID	Statements	#	%
M1	Learn new skills and technologies	30	76.92
M2	Learn how a real software system is developed in industry	17	43.59
M3	Play a positive role in this crisis	35	89.74
M4	Demonstrate my skills and expertise	23	58.97
M5	Challenge myself to do technically challenging tasks	19	48.72
M6	Gain experience and put it in my CV	27	69.23
M7	Build a network by meeting and communicating with new people	26	66.67
M8	Experience participating in a student initiated/led project	25	64.10
M9	Experience working on a crisis related software project	19	48.72
M10	To occupy free time	10	25.64
M11	Interested in learning more about the COVID-19 situation	24	61.54
M12	Others	3	7.69

TABLE III
LIST OF GENERAL CHALLENGE AND SURVEY RESPONSES (IN %). STA: STRONGLY AGREE, A: AGREE, SWA: SOMEWHAT AGREE, SWD: SOMEWHAT DISAGREE, D: DISAGREE

ID	Statements	STA	A	SWA	SWD	D	STD
C1	It was difficult for me to balance my university commitments and working on this project	2.94	8.82	26.47	14.71	32.35	14.71
C2	It was difficult to manage my mental health while working on this project from home	0.00	5.26	7.89	7.89	31.58	47.37
C3	It was difficult to manage my physical health while working on this project	2.56	2.56	2.56	7.69	43.59	41.03
C4	It was difficult for me to work on this project from home	0.00	7.69	5.13	12.82	33.33	41.03
C5	It was difficult for me to keep my attention away from distractions while working from home	0.00	17.95	15.38	12.82	33.33	20.51
C6	It was difficult to establish a work-life balance while working from home	5.13	20.51	23.08	7.69	20.51	23.08
C7	It was difficult to set up my own productive workspace while working from home	2.56	12.82	10.26	10.26	33.33	30.77
C8	It was difficult for me to stay motivated while working from home	5.13	12.82	15.38	20.51	25.64	20.51
C9	It was difficult for me to collaborate with the team through a purely online medium	2.56	12.82	12.82	17.95	28.21	25.64
C10	It was difficult for me to work in a purely online medium	0.00	7.89	5.26	18.42	44.74	23.68

C9). Despite this, we found some references in the open-ended questions, which indicates that team building and relationship forming was difficult due to having to communicate through a purely online medium. For example, a student mentioned that *"the sense of belonging and community was lacking a bit in my opinion"*, and another wrote *"having never met any of the other student volunteers in real life (...) was a little challenging"*. Other students described the effect of such a working style on team and project management. As an example, we have, *"It was also challenging to manage the team, especially when delegating tasks because many people would join the project but may not have real commitment"*.

2) Data Collection Challenges: The COVID-19 information dashboard is a data-intensive project. As such, data collection was one of the most dominant activities of the project, with 42.5% of participants indicating that they were involved in data collection. Hence, we presented the participants involved in data collection with challenge statements specific to data collection, shown in Table IV. Our analysis shows that approximately 76% of those involved in data collection agreed that it was difficult to find reliable and accurate data for the project (statement C11 in Table IV). Furthermore, 76% of them had difficulty finding up-to-date data (statement C12), and over 70% of them found it was challenging to find consistent data across multiple sources (statement C13). The analysis of Slack messages supports these results. For example, we found such messages in Slack, *"gov can make a mistake and it's hard for us to always keep an eye on it"*, *"they are always changing the format..."*, and *"due to the lack of a federal level information hub we have to manually collect some data for our app from different places"*.

Moreover, analysis of the open questions also highlighted the challenges associated with the government's reporting process in releasing information about COVID-19. One student commented that *"Governments release their data in different time, which requires us to monitor and collect data through the entire day. This increased the workload of the job"*, and another commented, *"state governments had disparate processes which made our jobs a bit harder"*.

Conversely, while collecting data was a challenge for many of the participants, the team did not consider understanding the data found on the sources difficult. Approximately 59% of

TABLE IV
LIST OF DATA COLLECTION CHALLENGE AND SURVEY RESPONSES (IN %). STA: STRONGLY AGREE, A: AGREE, SWA: SOMEWHAT AGREE, SWD: SOMEWHAT DISAGREE, D: DISAGREE

ID	Statements	STA	A	SWA	SWD	D	STD
C11	It was difficult to find reliable and accurate data	0.00	47.06	29.41	5.88	17.65	0.00
C12	It was difficult to find data that was up to date	5.88	17.65	52.94	5.88	17.65	0.00
C13	It was difficult to find data that was consistent across multiple sources	11.76	35.29	23.53	17.65	11.76	0.00
C14	It was difficult to interpret the data on sources we found	0.00	35.29	5.88	23.53	29.41	5.88

participants disagreed that it was difficult to interpret the data on the sources they found (statement C14).

RQ2 Summary. *The participants largely disagreed with the general challenge statements. The general challenges that were the most prevalent were establishing a work-life balance while working from home and balancing university commitments. The participants also voiced that forming relationships and team building was difficult as the project was entirely online. The students expressed more strongly that data collection was a significant challenge as it was difficult to collect reliable, accurate, and up-to-date data from the various government sources.*

D. RQ3: Strategies and Practices

We present a total of 15 strategy statements, of which 5 of were specifically related to data collection. The survey participants were asked to rate how often each practice or strategy were used. We considered a strategy to be have been commonly used if they were rated "Often" or "Very Often".

1) General Strategies: As shown in Table V, the most commonly used practices were related to communication management and managing team well-being. Statements S3 and S5, which were related to communication, had 92% and 87% of the participants indicating that they were common practices. These were practices the participants have adopted to address the communication challenges discussed in Section IV-C. The main form of communication between the project participants was through text messages rather than voice calls, as only 21% agreed that they have communicated through voice calls for a more efficient conversation (statement S4).

Some efforts were also made to manage individual well-being. To keep the team motivated, the participants often encouraged each other (statement S6) and celebrated project milestones as a team (statement S7). As responses to the open question, a few participants also mentioned practices to manage their well-being, such as having *"regular exercise, consistent sleep schedule..."* and *"...periods of relaxation..."*. Another participant mentioned *"building personal relationships with team members ... helped during isolation"*. About 72% of the participants also responded that they worked on a fixed schedule to manage their commitments. The open questions also revealed other practices in task management, with four participants mentioning that they keep track of tasks through reminders, and three mentioning referring to different resources to help them with their tasks.

We identified a few strategies that were less commonly practiced by the participants. About 56% of the participants rarely distanced themselves from the constant feed of COVID-19 news (statement S8), and close to 18% of the participants never did so. This strategy could have been difficult to practice as the majority of the tasks revolved around data collection. Another practice that was not as popular was to refer to similar sites for data visualisation creation (statement S9). More than 20% of the participants never adopted this practice, and about 36% did not do so frequently. This can be justified by the fact that only a quarter of the participants were involved in data visualisations. About half the participants also infrequently separated their work and personal spaces (statement S10), with only 46% stating they have kept separate spaces for different purposes.

2) Data Collection Strategies: Most participants frequently practiced the strategies presented in the survey, with participants agreeing that they are (very) often visiting data sources for most up-to-date data (statement S12) and cross-checking data across sources (statement S14). These practices correspond to the challenges in finding reliable and accurate data (statement C11) and finding data that was up-to-date (statement C12). The open questions also supported these strategies, with participants mentioning Twitter updates and referring to other sites for inspiration.

RQ3 Summary. *Frequent and clear communication through text was identified as one of the most commonly adopted practices. The participants also frequently showed appreciation and encouragement to other team members. As for data collection, the participants frequently visited trusted sources and cross-checked data to ensure the quality of data displayed on the website.*

E. RQ4: Technical and Soft Skills

In order to determine how much the participants felt they learned from their participation on the project, we presented a set of 16 skills (8 technical and 8 non-technical). Each participant was asked to rank on a numerical scale how confident they felt in each skill (0 being the least confident and 10 being the most confident) before and after the project.

TABLE V
LIST OF GENERAL STRATEGIES AND PRACTICES AND SURVEY RESPONSES (IN %)

ID	Statements	Never	Rarely	Sometimes	Often	Very Often
S1	To manage my workload, I worked on tasks with the rest of the team	2.56	10.26	38.46	35.90	12.82
S2	To manage my commitments to this project, I worked on it according to a fixed schedule	2.56	5.13	20.51	48.72	23.08
S3	To communicate more clearly, I used clear language in the messages I sent to teammates	0.00	0.00	7.69	35.90	56.41
S4	To communicate more clearly, I used voice calls rather than text messages for discussions	15.38	35.90	25.64	10.26	12.82
S5	To collaborate more effectively, I actively responded to teammates' messages	0.00	0.00	12.82	46.15	41.03
S6	To boost team morale, I encouraged and acknowledged the efforts of other teammates	0.00	7.69	15.38	38.46	38.46
S7	To boost team morale, I celebrated project milestones with the team	5.13	5.13	28.21	38.46	23.08
S8	To manage my well-being, I regularly distanced from the constant feed of news related to COVID-19.	17.95	25.64	30.77	17.95	7.69
S9	To create visualisations, I looked at how other COVID-19 projects visualized their data	20.51	10.26	25.64	28.21	15.38
S10	To keep a healthy work-life balance, I set up a productive workspace separate from my personal space	12.82	17.95	23.08	28.21	17.95

TABLE VI
LIST OF DATA COLLECTION STRATEGIES AND PRACTICES AND SURVEY RESPONSES (IN %)

ID	Statements	Never	Rarely	Sometimes	Often	Very Often
S11	To easily find accurate and reliable data, I maintained a list of trustworthy sources	0.00	0.00	12.00	41.00	47.00
S12	I regularly revisited data sources to collect the most up-to-date information	0.00	0.00	0.00	41.00	59.00
S13	To ensure data was consistent, I discussed any differences found across data sources with my team	0.00	6.00	12.00	47.00	35.00
S14	To ensure data was accurate, I cross-checked data with multiple sources	0.00	0.00	0.00	59.00	41.00
S15	To better understand the data, I did background research on topics related to COVID-19	0.00	6.00	18.00	35.00	41.00

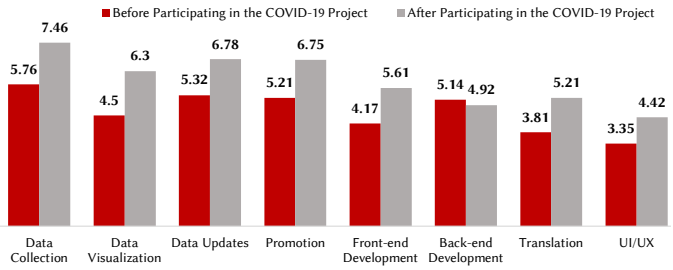

Fig. 3. The mean of the participants' confidence in technical skills before and after participating in the COVID-19 project

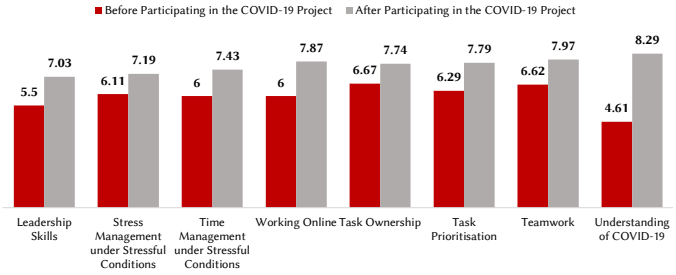

Fig. 4. The mean of the participants' confidence in non-technical skills before and after participating in the COVID-19 project

1) Technical Skills: As shown in Fig. 3, out of software development-related skills, participants grew the most in front-end development with 34%, while back-end development saw a drop in confidence by about 4%. This can be attributed to the lack of back-end for the COVID-19 information dashboard website, forcing back-end developers to learn and work in front-end development instead.

Moreover, analysing open responses from participants showed that participants gained great insight into the development process of a software project. These include version control, CI/CD, the usage of Git (particularly pull requests), and code reviews.

Participants who worked on data-related areas of the project grew 40% more confident in data visualisation and 30% more confident in data collection. No participants indicated their ability to provide data updates had declined, with confidence in that area growing by roughly 27%. In addition, other technical areas where the participants felt more confident were language translation (36%), UI/UX (32%) and promotion (30%).

2) Non-Technical Skills: Although the participants were abruptly forced to adjust to the unusual circumstances of the pandemic, they showed high levels of learning and adaptability. Fig. 4 indicates an overwhelming consensus among the participants that their understanding of COVID-19 grew by close to 80% through their experience working on the project. They also grew roughly 31% more confident in their ability to work online, with one student explicitly mentioning Slack as a useful tool for online work. Moreover, time and stress management under stressful conditions grew by 24% and 18% respectively, with no participants indicating they had regressed in their ability to manage these aspects even under the challenging circumstances.

All contributors recognised they had grown roughly 20% more confident in teamwork. Some participants who stepped up to lead in specific areas or in discussions reported they grew about 28% more confident in their leadership skills. Many students especially noticed a rise in self-confidence, expressing they felt more confident *"speaking up"* or *"talking a lot with*

sponsors". One student identified networking as an area of growth, saying the project was a *"great place to meet people"* and he *"made some connections [he] was able to use"* going forward.

Participants also reported they grew 24% more confident in their ability to prioritise tasks effectively, and 16% more confident in task ownership, both of which are skills related to workload management.

RQ4 Summary. *Participants showed overall positive growth in technical and non-technical skills, particularly data-related skills, understanding of the COVID-19 pandemic, and working online. Students especially appreciated learning about project development aspects such as version control and CI/CD. Back-end development was the only skill participants did not grow in due to the absence of a back-end for the project. The participants also grew more competent in other miscellaneous areas like translation, UI/UX, and self-confidence.*

V. Discussion

Based on this study's findings, we provide some implications for researchers, practitioners, and policymakers.

A. Implications for Research

1) Student Motivation: Silva et al. found that students were motivated to participate in OSS projects by rewards and for experience [11], [14]. Our study supports this with a majority of students expressing interest in learning new skills, gaining experience for their CV, and building a network. Additionally, we observed that students were motivated to contribute by wanting to play a positive role during the pandemic and to gain experience working in a crisis. This further extends prior research as it provides an altruistic view for student motivation. Future projects may want to leverage students as reliable and responsible human resources in dealing with crises.

2) Challenges and Growth: Prior studies on professional developers identified several challenges stemming from working from home during the pandemic, such as a poor work environment, poor work-life balance, and difficulties in collaborating [3], [15]. While these issues were also present in the student team, they were reported to a less significant degree.

We also observed that students had to balance their academic commitments, similar to professional developers balancing external commitments such as family [3], [16]. Students who participate in such projects may be more adept at handling multiple responsibilities when entering the professional environment, which is supported by increased confidence in their task prioritization abilities.

The primary challenge of the project was data collection. Irregardless, our findings suggest that the students were able to adapt to these difficulties through the employment of various data collection strategies. This resulted in students' growth in their data collection skills and contextual understanding of COVID-19. Future projects should encourage placing students in challenging environments as they may stimulate an improvement in skills.

3) Student Wellbeing: A major focus has been placed on developer wellbeing during COVID-19 [16], [17], as WFH has often been observed to have varying impacts on an individuals wellbeing. The students in this project were active in maintaining the wellbeing of the team, with students supporting and acknowledging each other to boost team morale. This is supported with a majority expressing that mental health was not a significant challenge while working on this project. The strategies adopted by the students in maintaining wellbeing while working under these situations may be translated to other student teams or professional teams.

B. Implications for Practice

1) Students: We observed that the students employed many strategies and practices whilst working on this project, and conversely, an overall disagreement with the presented challenge statements. Students who work on future projects can actively utilise the strategies discussed in this study to manage their project or team, especially if working online or within a crisis.

2) Educators: Proper management of the challenges in a project will affect the experiences and continual motivation of the students contributing to a project. Educators can leverage the challenges identified in this study, with the corresponding strategies, to help cultivate positive experiences while working. Additionally, educators can emphasise the benefits of working on a project in line with the motivations highlighted, such as gaining experience for their CV.

3) Government: As previously discussed, the participants primarily faced challenges with collecting data, as the dissemination of information was disparate and inconsistent. As the primary source of information for the students was government reporting, we recommend that efforts should be made to ensure the consistency and reliability of federal reporting across Australia. This may include presenting information in a consistent format or having a central information hub. This would be beneficial not solely to data aggregation projects, but to the general public seeking information on a crisis.

C. Threats to Validity

1) Threats to External Validity: Threats to external validity refer to how our results may be generalized to other software teams of a similar nature [18]. In this study, we examined only one project team in the context of the COVID-19 pandemic. Different student teams may have different experiences depending on the nature of the students or the type of software being developed. Our findings may not generalize to other student software projects. However, the proposed methodology may provide a guideline for further studies to be conducted on a larger scale.

2) Threats to Internal Validity: Threats to internal validity refer to the conditions present while conducting this study. We primarily ascertained the participants' opinions through Likert

scales. The statements presented may have been biased based on preconceptions of the author. However, these statements were derived from a pilot study conducted on communication between the team members and existing literature to reduce this bias. Furthermore, the statements were finalised after several iterations and taking into account the opinions of multuple authors. This helped further reduce bias during the pilot study. We paired open questions with each Likert scale question to allow the participants to express further views above the statements presented. While their responses could have been influenced by the preceding statements, we emphasized that further views should be separate from the presented statements. A monetary incentive was also provided to the participants to encourage a higher quality of response. We do not present role-specific statements aside from data collection as the pilot study indicated that there were few role-specific challenges present in other roles.

VI. Related Work

This section summarizes the key literature around the topic.

A. Software Development during the COVID-19 Pandemic

The pandemic has forced many organizations to adopt the work from home (WFH) policy, requiring employees to work remotely from home. A number of studies investigated how this policy has changed the way developers work and its effects on developers in terms of productivity levels and well-being. Ford et al. [3] and Forsgen [19] identified lower initial productivity of developers in the early stages of the pandemic, which eventually stabilized or recovered as developers became accustomed to the new policy in place. The studies done by Ford et al. [3], Bao et al. [15], and Ralph et al. [16] revealed that developer productivity is affected by their adaptability to the change in work environment and ergonomics. In these studies, developers with increased productivity quoted benefits of WFH, such as better work-life balance and flexibility in working hours. Conversely, flexibility in working hours also hindered productivity when it is not well-managed by developers [3]. Other reasons for lowered productivity quoted were difficulties collaborating with others [15], poor work environment, and distractions [3].

WFH also affected developers' well-being both positively and negatively. Developers whose well-being improved commonly mentioned better work-life balance. Varying reasons, such as less physical activities, less social interactions, and difficult communication, were quoted by developers suffering from worse well-being [3]. Longer workdays and working during weekends were also observed by Forsgen [19]. However, the WFH policy has encouraged more collaboration on OSS, evident from the increase in the number of developers in numerous projects.

As these studies examined professional developers, our study provides insights into how students fare in a different work environment and its impact on their software development.

B. Education during the COVID-19 Pandemic

Temporal closures on the majority of the schools worldwide due to the COVID-19 pandemic [20] had a tremendous impact on the education system in various countries [21]. In particular, schools transitioned to remote learning to continue with the curriculum. Bao [22] looked into challenges and provided suggestions to improve the overall experience of remote learning. It was realized that students generally had lower motivation and engagement levels with remote learning. In contrast to this, Gonzalez et al. investigated how well university students coped during the pandemic in terms of performance and found that students developed better studying habits during this time [23]. Education in medical schools during the COVID-19 pandemic were studied more extensively. Some examples include [24]–[26], where delivery methods of different institutions were explored and evaluated via student experience with the different methods adopted.

The aforementioned studies gave insights to how the education sector responded to the pandemic and to some extent on how students are responding to new delivery methods. Yet, limited or no studies have focused on the experience of software engineering students in their learning and development process. Thus, our research aims to fill this gap by characterizing the student experience while working on a software project during the pandemic.

VII. Conclusions

This paper has studied a team of volunteering students working on a software project (i.e., the COVID-19 information dashboard) during the COVID-19 pandemic to provide accurate, reliable, and real-time COVID-19 information for Australians. This dashboard has been largely acknowledged by the Australian community as it has approximately had 10.5 million visits as of October 15, 2020.

We conducted an online survey to understand the students' motivations to participate in the project, their challenges, the strategies they used to mitigate the challenges, and the skills they learned throughout the project. We have observed that playing a positive role in the COVID-19 crisis and learning new skills and technologies were among the most cited motivating factors for the students. The participants mentioned difficulties in balancing work-life and forming connections with team members, as a few of the challenges they faced during their work on the project while socially isolating. Some of the strategies they used to minimise these challenges were frequent and clear communication in the team and uplifting team members with words of encouragement. The participants indicate an overall positive growth in their skills, especially data-related skills, understanding of the COVID-19 pandemic, working online, and an overall increase in their confidence. It is our hope that our research provides a clearer, deeper picture on student response and experiences to crises, and contributes to research in identification of appropriate challenges and solutions in crisis-based software development.

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