

To Work From Home (WFH) or Not to Work From Home? Lessons Learned by Software Engineers During the COVID-19 Pandemic

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Abstract. This research investigates software engineering during the COVID-19 pandemic with a focus on the lessons learned and predictions for future software engineering work. Four themes are explored: Remote work, Team management, Work/Life balance, and Technology/Software Engineering Methods. Our research has demonstrated that software companies will derive tangible benefits from supporting their employees during this uncertain time through ergonomic home offices, listening to their concerns, as well as encouraging breaks and hard stops to boost long term well-being and productivity. It shows that communication and collaboration tools, critical to project success, have been utilised. The hiring of new talent has been reimagined, with managers playing a vital role in the process. The insights gained are significant as they will assuage some pre-existing concerns regarding remote work, creating a new understanding of its role in the future. Looking to a post-COVID-19 future, we envision the rise of hybrid software development working arrangements, with a focus on the Working-From-Home to Not-Working-From-Home ratio - WFH : NWFH - perhaps colloquialised as *Home : Not Home (HNH)*. For many this ratio will be neither 100:0 or 0:100, the former would lead to team breakdowns, developer isolation, difficulties onboarding and too many communication gaps, the latter would lead to disaffected employees. We identify plausible future software engineering working arrangements, noting that there are challenging times ahead for employers and employees as they navigate this *HNH* future, but there are benefits for both parties in getting the balance right.

Key Words: Software Engineering, COVID-19, Working From Home (WFH), Not Working From Home (NWFH), Home Not Home (HNH)

1 Introduction

On 30 January 2020, the World Health Organisation (WHO) declared Coronavirus Disease 2019 (COVID-19) a global health emergency based on the growing number of cases worldwide [47]. As a result of the COVID-19 pandemic, governments worldwide imposed certain restrictions on their citizens [48], in many cases preventing non-essential workers from attending their habitual workplaces, thereby catapulting large swathes of the population into working from home (WFH) mode. While the rapid and widespread adoption of WFH regimes has been highly disruptive, it also provides an opportunity to trial a different type of working pattern for many sectors, and perhaps has accelerated the transition to remote working for certain types of employees. For some firms in the software engineering sector, infrastructure and policies needed for WFH were in place prior to COVID-19, therefore smoothing the transition to ‘stay-at-home’ policies [1]. But there are some key differences between working from home on an ad hoc, part-time or semi-structured basis and having to work entirely from home, and therefore even for firms with pre-existing WFH policies, their work practices will have required adaptation. We must furthermore also acknowledge that WFH during non-pandemic times is acutely different to WFH during a pandemic.

This research aims to examine the effects of COVID-19 on the software industry and understand what these effects could mean for the future of work, through the exploration of four key themes: remote work, team management,

work/life balance and supporting technologies. These themes encapsulate the following research questions that will be considered:

RQ1: What have COVID-19 restrictions taught software engineering firms about WFH?

RQ2: How has software engineering team management changed throughout COVID-19 restrictions?

RQ3: How has the welfare of software professionals been affected by WFH during COVID-19 restrictions?

RQ4: What changes can be observed in development methods and technologies during COVID-19 restrictions?

Section 2 outlines the research methodology, with Section 3 providing an analysis of the related literature. Section 4 briefly discusses the known limitations. Section 5 contains concluding remarks, including a summary of the findings and possible future software engineering work patterns.

2 Methodology

Research for this paper has been conducted in the form of a multivocal literature review [49] which incorporates peer-reviewed publications (termed ‘white’ literature) and carefully selected non-peer-reviewed materials (termed ‘grey’ literature, e.g. government reports and moderated online blogs). Four key topics were identified: remote work, team management, work/life balance, and development methods / supporting technology. Research papers were found using digital repositories/search engines such as *SpringerLink*, *ScienceDirect*, *IEEE Xplore* and *Google Scholar*. Search strings started out broad, including ‘software industry and COVID-19’, ‘software engineers COVID-19’ and ‘software development and COVID-19’. After an initial reading of the documents returned, search strings were further refined to a combination of the following; ‘software development and remote work COVID-19’, ‘software engineering managing teams during COVID-19’, ‘effects of remote work COVID-19’, ‘collaboration software engineering COVID-19’, ‘social interaction changes due to COVID-19 software engineers’, ‘agile methodology during COVID-19’ and ‘changes in technology covid software companies’. A cascading set of search strings were later employed as the research space came to be better understood.

2.1 Inclusion/Exclusion Criteria

Sources used in this research had to be available in full text online and in English. When researching white literature, papers found with a relevant title were assessed and marked for further reading in a compiled reading list deemed directly relevant. These papers were ranked on reliability according to their number of citations, though it is understood that this alone is not a reliable means for quality differentiation. Researching grey literature required more caution and only those that were deemed entirely relevant and reliable were included. For example, publicly available articles from significant broadcast outlets, e.g. the BBC, were included. Exclusion criteria included non-relevant papers, and materials whose content was not accessible in full format or in English or whose provenance or authenticity could not be established. Table 1 outlines the breakdown of the white literature incorporated in this research, showing that a total of 51 separate sources were considered for inclusion, with this list later being reduced to 39 individual works based on the application of the inclusion/exclusion criteria.

3 Analysis

3.1 Remote Work

In response to COVID-19 related restrictions, many in the software engineering industry shifted to exclusively WFH. In this section we examine the reported material on WFH during COVID-19 and answer **RQ1**: *What have COVID-19 restrictions taught software engineering firms about WFH?*

3.1.1 Difference between Remote Work and WFH during COVID-19 restrictions

Since the established benefits of WFH may not entirely apply during COVID-19 restrictions [2], it is important to distinguish between WFH in *normal* working times and WFH as a result of COVID-19 restrictions. Rather than

working in a fully provisioned and ergonomic home office, some workers have had to make do with makeshift offices and the distractions of communal and family agents (it is not just an individual worker that is at home in an otherwise quiet dwelling, all household occupants, including children, may be present in the dwelling) [3]. Stress, moving to an improvised and sub-optimal home office, and lack of childcare may reduce developer productivity [3], it could result in developers being unavailable for regular team ceremonies during heretofore regular work hours, for example while attending to home schooling. For some software developers, therefore, WFH during COVID-19 restrictions might be a stressful and frustrating experience. Take for example a young adult, still living at home with a guardian(s), and perhaps with other younger children in the household, with no dedicated workspace and sharing a small bedroom; and perhaps even with family members or friends directly affected by COVID-19. Workers with their own children may be committed to home-teaching for certain hours of the day. These are not *normal* circumstances for productive software development. Other workers may be more fortunate and may enjoy well-provisioned home offices that are well insulated from distraction. There is no single characterisation that can be formed to describe all possible household arrangements during COVID-19 restrictions, the impositions in common in many nations are a restriction on movement outside the home (other than for essential purposes) and the stress associated with an unfolding pandemic.

Table 1. White Literature Overview (R=Reviewed; C=Cited).

Source	R	C	Source	R	C
SpringerLink	6	5	IEEE Xplore	3	1
arXiv	7	6	ACM Digital Library	2	1
NBER	3	2	IGI Global	1	1
SSRN	2	2	Empirical Software Engineering	1	1
International Journal of Software Engineering & Applications	1	1	British Journal of Industrial Relations	1	1
Journal Of Management Studies	1	1	Annals of Operations Research	1	1
Journal Of Sustainability	2	1	Journal of Diabetes & metabolic syndrome	1	1
Journal of Innovation Management	1	0	Journal of Cleaner Production	1	1
Journal of Information Systems Management	1	0	SHS Web of Conferences	1	1
European Journal of Information Systems	1	1	Public Administration Review	1	1
Journal of Organisational Computing & E-Commerce	1	0	Innovative Technologies & Scientific Solutions for Industries	1	1
International Journal of Information Management	2	2	Journal of Organisational Behavior	1	1
Business & Information Systems Engineering	1	1	Gender, Work & Organisation	1	1
Journal Of Applied Psychology	1	0	Human Relations	1	1
Journal Of Management Research	1	0	Journal of Vocational Behavior	1	1

New Technology, Work and Employment	1	1	Emerging Infectious Diseases	1	1
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3.1.2 Lessons Learned from Remote Work

Before COVID-19, some managers were sceptical about WFH due to worries concerning reduced developer focus, productivity decline and team cohesiveness [4]. However, COVID-19 impositions forced managers to tackle these fears as opposed to using them to insist on a traditional workplace location [5]. Studies show that WFH helped maintain operational capacity during COVID-19 when workplaces were inaccessible [6], with some suggestion that developer work output showed little change when working in an office or WFH [5]. These findings also show that WFH did not affect how developers dedicated their time to work tasks, and up to this point, there has been no reported significant change in performance as measured by lines of code and commits, except for in cases where an increase has been observed [7]. Moving to a partial or full WFH paradigm might place an emphasis on work output rather than hours of work. While no direct evidence was found in support of it, it could also be the case that reduced attrition levels and increased flexibility in annual leave postponement have resulted in a temporary rise in productivity, however, as the COVID-19 pandemic recedes, both of these effects will return and perhaps even increase slightly for a period (with a corresponding reduction in productivity).

Perceived productivity levels differed among developers when WFH, the majority of developers reporting that their productivity had not changed or had even increased, while a minority believed their productivity had decreased [8]. However, this decrease in productivity was more prevalent at the start of the transition to WFH and after a longer period, the productivity levels of the minority were reported to increase again [8]. It is tempting to conclude that reported decreases in productivity are temporary and the result of the initial transition to WFH, but caution is advised when interpreting the data at this point as data is limited, forced WFH arrangements are as-of-yet relatively novel, and the pandemic is still unfolding. Increases in work conflict and work pressure have also been reported during this novel period [9], and developers' work has been reported as intruding into home lives through longer working hours, thinking about work during free time and in some cases, leading to exhaustion [10]. Despite these downsides, some developers have reported an increased level of focus and a greater sense of "being in the flow" when WFH [7], resulting in improved problem-solving capabilities and code production.

As a result of WFH during COVID-19, the importance of ergonomic home offices has been observed, with those with more ergonomic home offices reporting greater well-being and increased productivity [3]. Developers with young children reported increased noise levels leading to distraction, while developers living alone tended to have superior ergonomic arrangements in place [3]. Additionally, access to remote desktops and internet bandwidth were one of the biggest challenges that developers faced during COVID-19 restrictions [8]. Therefore, software companies which supported their developers in establishing more ergonomic offices (through chairs, noise-cancelling headsets etc.), better internet access and hardware (additional monitors, more powerful machines etc.) increased the productivity and well-being of their workers [3].

Some significant additional positives are also reported by developers WFH during COVID-19 restrictions, including much less time commuting to work with associated stress reduction, improved sleep, and increased time in the company of their families [8], which for some, may have boosted morale and quality of work. On the initial transition to WFH, some developers started working earlier in the morning as a result of having no work commute but also worked later in the evenings, leading, in some cases, to burnout [7]. This underpins the need to consider imposing 'hard-stops' and logging-off time, and if WFH is to become a longer-term arrangement, such measures will ultimately be instrumental in sustaining a healthy, productive and happy workforce. Perhaps simple measures such as email batching/scheduling during certain hours (and for certain employees) can assist with this agenda. Whilst some employers might think such steps counter-intuitive, most businesses aspire to long term success and in the knowledge worker-driven software sector, this requires the retention of productive employees over the longer term.

3.1.3 Future Predictions concerning Remote Work

Predicting the future is a perilous and fragile pursuit, but it is essential that we do so in order that software developers and development firms can prepare for future working arrangements. It seems that the trend towards WFH (that was already a feature of the technology sector) has received an abrupt acceleration, perhaps bordering on a sudden transformation, with a Gartner CFO survey reporting that 74% of companies intend to shift some employees to *permanent* remote work after COVID-19 [11]. It is reported that Twitter has announced to its staff that they can continue WFH permanently [12], whilst 89% of employees based in New Zealand would like to continue WFH after COVID-19 [13]. Major software companies such as Microsoft, AirBnB and Facebook informed their employees that they could WFH indefinitely or extend the WFH policies providing specific support [14]. Therefore, we see an increasingly positive attitude towards WFH in the future with COVID-19 restrictions accelerating the rise in flexible work arrangements and WFH [1]. Future arrangements are perhaps best described as “*work will become something you do, not a place you go*” [15].

Flexible work arrangements, including the facility to work remotely, are reported to be an important means to balance work and life commitments [9]. A future dominated by WFH has implications for demand for expensive city-based real estate and office space. Major tech regions in the US such as San Francisco are hampered by high housing rent and the move to WFH could allow developers to continue to work in these technological focal points while avoiding high rental costs, thereby increasing their disposable income [16]. However, some companies may follow Facebook’s path of adjusting compensation to the cost of living in the employee’s location [17]. There remains a lot of uncertainty regarding these future arrangements, high quality software developers are often in short supply, difficult to attract and retain, and therefore companies will need to be careful in the financial treatment of their employees. Companies can expect savings in reduced physical office outlay costs, they can aspire to healthy productivity levels (as note in the earlier commentary), but they currently must operate in an expansionary technology sector where talent supply lags talent demand.

The success of WFH during COVID-19 is largely due to fully distributed teams created out of necessity. Once workplaces reopen, it is likely only part of these teams will opt to WFH while others prefer to work in the office, therefore resulting in partially distributed teams. This could negate some of the benefits of WFH especially in terms of communication, personal recognition and socialisation [7]. We further postulate that there could be an age divide in WFH predilection, where youthful and single workers might prefer city settings with all the entertainment and social engagement opportunities they offer, whilst older developers with (or without) families might opt for greater living space and generally more tranquil living. Although these observations might initially amuse some readers, they could result in significant organisational challenges for some companies. This research, and discussions associated with it, suggest that a complex cocktail of factors will need to be considered by firms in designing blended WFH policies. For example, an increased duration of employment in a firm may reduce the basic need to be physically present in an office, while increased commuting distance and duration might increase the attractiveness of predominately WFH.

3.2 Team Management

Changing work patterns in response to COVID-19 related restrictions might be expected to coincide with changing work management practices. In this section we examine the reported material on WFH during COVID-19 and answer **RQ2**: *How has software engineering team management changed throughout COVID-19 restrictions?*

3.2.1 Management of Teams

The resilience of software managers has witnessed significant challenge since the introduction of COVID-19 restrictions, they have had to overcome their own personal life upheaval and at the same time step up and lead their teams with confidence and maintain developer motivation [18]. The well proven disciplines of managing by casual observation and *ad hoc* intervention to encourage and provide feedback were no longer viable when WFH [7]. Instead, managers relied on more structured, scheduled connections with meetings taking place over video conferencing. Project management and reporting practices which served them well in the pre-COVID-19 work environment needed to be tailored for the new reality of a massively dispersed team, with techniques like daily

stand-ups and other formal checkpoints proving popular for discussing task progress and obstacles [19]. Opportunities for informal progress reports that would traditionally present at lunch or in the corridor or at the coffee dock are eliminated if WFH, and therefore managers and their staff alike will need to identify replacement mechanisms for this vital communication, and this could result in more formalised and regular virtual update sessions. For some companies, moving daily stand-ups online can help reduce this communication gap.

Just as the impact from individual home working environments was highly varied, so too is the impact on managers depending on their pre-existing project and team circumstances. Setting up a new project introduces different risks and tasks when compared with the continued operation of an up-and-running project, and other factors such as pre-existing team working arrangements can impact greatly. For example, managers in organisations with established distributed software engineering and WFH practices avoided the time and effort involved in establishing secure, stable remote access to services and data, designing and implementing distributed software engineering processes and educating teams in the new ways of working [8]. Moreover, managers new to WFH practices were likely to have doubts that their team members were WFH effectively or even lacked the motivation to work in the face of the additional challenges of WFH during COVID-19 [7].

Initiating new projects, and especially new teams, traditionally involves high levels of personal interaction as teams work through the forming-storming-norming-performing stages of group development [20]. And new teams faced with challenging new projects might benefit from co-located interaction: despite the abundance of tools available for remote brainstorming and problem solving, it is reported to be much more difficult to initiate new ideas without in-person interaction [7]. Scrum masters and Team leaders might now have to schedule informal events into the working day/week to create a sense of spirit and engender the team culture. This may be via team coffee mornings or kick off meetings with a few minutes of catchup to mitigate the effect of the constant online meeting grind. This important aspect of building and keeping teams together through the social fabric of communication, we suggest, will require some significant re-thinking in a full or partial WFH organisation.

3.2.2 Communication and Collaboration

For many organisations, COVID-19 restrictions had a significant impact on the communication and collaboration of teams, leading to a need for a rapid change in previously used methods [21]. Technologies which had been used 10-20% of the time pre-COVID-19 restrictions were being used 90-100% of the time whereupon restrictions were suddenly introduced, resulting in an explosion in demand for communication tools such as Zoom, Slack and Microsoft Teams [22]. In March 2020 alone, daily active users on Zoom and Microsoft Teams increased by 67% and 120% respectively, with Slack adding an additional 7,000 paying clients [23].

The use of digital media-led interaction has resulted in workers not feeling connected to the organisation as the quality of communication is considered to be inferior [5]. Developers reported that team socialisation levels had dropped with the result that teams had become less *connected* [7]. A study showed 74% of respondents missed social interactions with colleagues and 51% reported a decrease in their communication ease with colleagues. The ability to build trust with colleagues is critical for collaboration but can be harder to achieve when WFH [8]. A decline in team cohesion was observed, with 57% of respondents reporting a decrease in their ability to brainstorm with colleagues [21]. There had been a significant decrease in pair and mob programming, which for many teams are fundamental to the success of the project, aiding the ability of team members to solve complex problems by working on them together [7]. While this was a challenge, it was not one that went entirely unaddressed, some teams used physical replacements such as small whiteboards and drawings on paper as an alternative way of brainstorming, while others used online tools such as Mural [17].

When WFH, developers had flexibility in how they work, giving them greater control of when to engage and disengage with colleagues which created opportunities for spells of deeper, more concentrated work [8]. Many distributed team members reported that they had more positive experiences WFH [7]. Although it has been difficult to duplicate the collaboration that happens in person, many have adapted, assuring executives that work can be done even when their employees are not together in an office [24]. Companies have also been innovating new ways to engage with their customers, while their customers are discovering that their needs have continued

to be fulfilled through these new methods [24]. We shouldn't expect that online and virtual engagements can instantly match or surpass traditional face-to-face human engagement with all the non-verbal cues and communication that entails, they might always be inferior. However, we may also have undervalued the extent to which technology could facilitate a different type of working, only embracing it to its full potential in response to an emergency global threat.

3.2.3 Hiring and Onboarding

The COVID-19 job market was unlike anything previously seen in economic downturns, unemployment soared in sectors such as hospitality and aviation, while job openings remained at extraordinary levels elsewhere depending on the industry, business function and skill [25]. As companies were forced through a digital transformation in order to support WFH, the demand for developers experienced in distributed software engineering practices and WFH remained high [26]. With hiring being conducted virtually, the process needed to be reworked to ensure the candidate experience was a high quality, professional experience that reflected the company's image and culture. To help both the employer and the employee make informed choices, efforts were made to extend the number of hiring organisation staff involved throughout the selection process by increasing the number of formal interviews and/or conducting informal group events [27, 28].

Effectively onboarding new employees can take time as they grapple with culture, technology, products and new teams, and doing so remotely made it more difficult for the new joiner to gauge company norms in terms of pace of work and communication style, also making it difficult to build connections to the team and the company [29, 30]. These are not positive developments for either the firm investing in the recruitment effort, or the individual trying to integrate into their new company, and could lead to frustration and stress for both parties. Being virtual withdraws vital opportunities for impromptu learning or collaboration with colleagues, and it also reduces the opportunity for informal feedback and guidance. These are particularly important observations, as while companies might satisfactorily *cope* temporarily in the face of an unprecedented disruption through leveraging the strength of existing personal relationships (perhaps forged over many years or decades working alongside each other), the same levers will not aid the virtual onboarding and integration of new workers.

Research conducted by Gallup research suggests that managers account for at least 70% of the variance in employee engagement [32]. Hiring managers must look to improved strategies for virtual training, knowledge sharing, feedback mechanisms and building a sense of connection with their teams if they are to succeed in retaining new talent [17]. The role of the hiring manager in the successful onboarding of new talent is arguably even more important in this new and still emerging world of WFH. And this is not just an issue for those managers responsible for hiring, it is also the team leaders, line managers, technical leaders and middle managers who carry a lot of responsibility for this concern. The well-trodden maxim that "people join companies but leave managers" [31] might, we suggest, be generalisable to "people leave other people", and therefore everyone in a software development team and the functions surrounding the team (from HR to IT to Finance) must adapt and create the time to virtually integrate new hires in a WFH future. This is one cost which might be initially overlooked in a race to a WFH future. Furthermore, the reduction or removal of various informal meeting and discussion occasions might, we suggest, limit the ability of developers to socialise and build their career within an organisation through social networks.

3.3 Work/Life Balance and Well-being

With the disruption of COVID-19 and its associated restrictions on socialising and individual movement, in this section we address **RQ3**: *How has the welfare of software professionals been affected by WFH during COVID-19 restrictions?*

3.3.1 Work/Life balance

Some have valued the benefits of WFH (e.g. no work commute) and have designed their work time around other life activities, in some cases this was essential to ringfence hours in the day when they could work on challenging

software tasks with relatively high levels of concentration [33]. However, research suggests that this flexibility comes at a cost, and that it has led to an increase in daily working hours [33]. Other evidence corroborates that developers are working longer and goes further in suggesting that this is not viable over the medium to longer term [34]. Specifically, it is reported that due to COVID-19 disruption, developers' work days have increased by up to an hour a day, including weekends. More specifically again, it is non-work related interruptions around the house that are cited as a source of disruption which leads to longer working days when calculated by summing the hours [34]. Additionally, the lack of 'hard stops' at the end of a work day, developers taking less breaks and shorter lunchtimes due to the absence of a social component have also led to this increase [7]. GitHub, a global developer platform that can be used to monitor developer activity, exhibited apparent increased work volumes in March 2020 when COVID-19 restrictions were introduced [34]. Some interesting reasons for this have been suggested, including the fear of losing one's job in uncertain economic times and pressure from management to push products to the market to take advantage of opportunities [34]. However, the evidence for increased output and productivity should be carefully evaluated (more code commits does not equal higher productivity) and if higher productivity was a real phenomenon, it might not be sustained or sustainable. Perhaps faced with an emergency, some people can find pockets of untapped productivity that are only available during emergency response.

At present, there are various reports of software developers working longer days but there is uncertainty as to the medium to long term affect on productivity (as identified in Section 3.1.2). However, there is currently an absence of robust data on productivity on WFH as the experiment is underway amid a global pandemic and longer-term potential gains and fallout are unknown. Plus, longer working hours do not necessarily deliver better quality work or improved total productivity over time (nor does it indicate the converse either). However, tasks undertaken later in a day when tiredness levels are higher might take longer to complete and be more error prone, and a sustained pattern of that type of work might play into significant accumulated exhaustion at a future point. Software engineers are well aware of the perils of accumulating technical debt in their products and take explicit steps to contain it [51], but they may be less aware of the dangers of burnout [50] and may not have explicit steps in place to detect and avoid it. Teams that allow flexibility and durable work schedules whilst looking out for ways to prevent burnout will keep colleagues happier resulting in better productivity over time and across the workforce [34].

3.3.2 Social Interaction

Prior to COVID-19 disruption, WFH was reported to contribute to a sense of isolation but it has been suggested that this area requires further investigation during the COVID-19 pandemic as many people have faced obstacles such as depression and higher levels of stress due to loneliness [35]. The social isolation phenomenon is complex and alternative research has argued that some professionals enjoy working in isolation and that it does not result in feelings of loneliness for everyone [36]. Among software developers, research has reported that 74% missed having social interaction with colleagues and that they had difficulty finding other ways for low-effort-in-person social interactions, such as coffee or lunch breaks, that enabled colleagues to build social connections and maintain companionship [21]. In software development settings, the need for social interaction is reported to be important as it provides colleagues opportunities to build trust with one another, not through structured or planned interaction such as stand-up meetings, but through unplanned social interactions [8], things such as chats at the coffee dock. This *trust* element is not easily measured and its effects on human behaviour are nuanced and the subject of some debate [52], but trust in colleagues is considered crucial for collaboration [8] and developing trust may be difficult to achieve when WFH and in the absence of unplanned face-to-face interactions that provide the opportunity to develop a sense for another person. Against a backdrop of declining social bonds and team unity when WFH [21], employers may need to be vigilant in designing and policing mechanisms that enable opportunities for trust building and sustaining.

Although effective engineering procedures and collaboration tools are important for productivity, comprehending the way in which developers socialise, communicate with one another and assist one another is just as important [21]. Furthermore, peer learning provides an effective set of circumstances for social interaction and gives an

opportunity for employees to learn technical and soft skills from each other [37]. Other improvements encouraging social interactions within teams remotely consist of teammates to be more understanding when it comes to WFH scenarios, to motivate their teammates to give their opinions and take part and advise managers how to direct their employees WFH [8]. Perhaps in the longer-term experience of WFH – and especially if it is to prevail as a traditional employer-employee model – software engineers and all those involved in the software engineering ecosystem may have to rethink their approach to trust building, perhaps learning to depend more on measurable and observable deliverables and commitment over time than on the time-honoured skills of gaining a likeness for an individual through more light-hearted and social discourse. But still there will be challenges in this space, especially if it is a sense of association with others that forms an important element of one's work experience, since unplanned low-effort-in-person interactions that rule this sense simply will not occur virtually. A highly virtualised environment therefore contains perils for both employers and employees.

3.3.3 Wellbeing

Some of the positive effects of WFH have already been identified in earlier sections and include the absence of a stressful daily commute. But for some individuals, COVID-19 has been reported to have a negative effect on a developer well-being, which is thought to commonly affect their productivity [3]. An individual's wellbeing while WFH is impacted by their emotional stability which influences how one is able to control their emotions during stress [3]. Factors including changes in flexibility of work and location are related to the welfare of a worker as they affect health both mentally and physically [8]. The experience of WFH can vary depending on one's level of emotional stability and for employees with low emotional stability, WFH can have a negative effect through social and psychological strains [3]. The reasons for the reported reduction in developer wellbeing are multifaceted and include the fear of COVID-19 itself, poor ergonomics, the amount of work a developer is expected to complete and the job security one experiences [3]. Firms will need to design mechanisms to address employee wellness, examples of which might include structured virtual exercise programmes and invited expert speakers on topics related to wellbeing.

Companies such as Microsoft have introduced mechanisms to improve the WFH experience for employees including activities and resources to aid physical and emotional well-being [8]. Companies can continue to support their employees by paying attention to their emotional wellbeing and providing assurance that lower productivity can be acceptable at certain times and in response to certain external conditions [8]. This can develop loyalty to the firm and for some individuals this holds strong currency.

3.4 Technology and Software Engineering Methods

The rapid and widespread transition to WFH in response to restrictions imposed by COVID-19 has necessitated some changes in technology and practices and is the focus of **RQ4: What changes can be observed in development methods and technologies during COVID-19 restrictions?**

3.4.1 Agile Methodologies

Research claims that agile development teams adapted well to the COVID-19 context [39], that the release frequency of agile teams did not change significantly as a result of practices already in place as well as knowledge and task management tools used such as Jira and Confluence. Other common agile practices such as the use of Kanban boards can be digitised and increase the clarity of workflow within distributed teams as well as between teams [40]. Increased involvement of the Product Owner is reported during COVID-19 restrictions and greater emphasis is placed on Daily Stand-Ups with teams using them as an opportunity to synchronise and share information [41]. However, distractions during Scrum ceremonies have been an issue when WFH as team members respond to emails during Scrum meetings [42]. Moreover, one study found that team collaboration is reduced as there are less discussions relating to user stories or project complexities, and this is considered to limit the effectiveness of the agile approach [38]. Furthermore, meetings with clients were reduced when WFH due to low internet connectivity, timing issues and availability which have made it difficult to maintain client satisfaction

[38]. However, this study also shows that in some cases attendance at Scrum meetings is declining which raises major concerns, but little evidence of this particular issue was identified elsewhere.

The research indicates, therefore, that agile software development can support an effective response to WFH during COVID-19, but that some agile practices and techniques might need to be both adapted and better policed to maintain collaboration and productivity [43]. For example, the location and time of Scrum meetings could be adopted to allow individual teams to self-organise for face-to-face team interactions at a location of their choosing (i.e. not necessarily in the company office space). It may also be beneficial to consider the adoption of alternative scrum/agile productivity metrics [63].

3.4.2 Technology Used in Software Development

One study found that WFH had different effects on productivity depending on which software framework was utilised [41]. It was observed that WFH had both positive and negative effects on development using C++ but only negative effects on Java development [41]. Furthermore, productivity decreased for developers working on server projects compared to application projects when WFH [41]. This could be due to server projects typically having a large number of components which requires more collaboration between teams. Smaller projects were less affected by the shift to WFH than larger projects and this could also be caused by the high collaboration required in large projects. Based on this data, companies considering new policies for WFH in the future would take account of the project size, type and software frameworks utilised on an individual project basis.

Many software start-ups were under pressure to quickly address uncertainties as a result of COVID-19 [44] and a transition to greater levels of cloud computing helped to reduce those concerns [45], along with various web enabled technology that promote information sharing (e.g. google docs and google sheets). Being an information technology model involving servers and networking [46], cloud computing support employees WFH as data is stored and managed on cloud based servers [45]. In order to reduce uncertainties and increase productivity during COVID-19 restrictions, it is necessary to provide access to technologies required to remotely test, build and debug software systems [41]. It is also important to conduct training and workshops for employees [10, 24] to increase awareness and understanding of the various technologies employed in firm.

One study reported that during COVID-19 associated WFH, developers spend less time bug fixing and more time on documentation, testing and learning [5]. Developers are also reported to spend less time in meetings [5] and may be more focused on improving their skill sets and capabilities. It is not entirely clear how to interpret some of this data, but it does introduce some cause for concern. Meetings are an important vehicle for information exchange and risk reduction, especially in agile software development, and if less time is being spent in meetings it may be resulting in lower levels of information exchange and higher levels of risk.

A participant of one study stated that their teams have and will continue to “*treat their tech stack as if they had to work from home at least 2 days a week. This way things such as VPN, workstations, deploy pipelines, local builds, etc are naturally able to support remote workers*” in order to make their company more productive [8]. This is an interesting insight, and companies having invested in enabling WFH may seek to derive full value from the infrastructure and the knowledge that employees can be called upon to attach to the work environment at any time. This motivation conflicts with emerging legislation designed to protect employees from abuse in situations where employers may contact them out of work hours [53]. However, if employees seek the benefit of flexibility (for example to spend time with family at times during the day or to get exercise) then it would not be reasonable to also expect to disconnect at the traditional end of the workday. Perhaps significant work is required to rethink the full impact of legislation designed to protect employees’ interests in a WFH paradigm. It has also been observed that collaboration on open source projects has significantly increased throughout COVID-19 with pull requests being merged at a faster pace than previously [34]. This could be the result of enthusiast developers contributing to projects that interest them in the absence of many other outlets during restrictions (and which might also form part of their regular working deliverables).

4 Research limitations

This work was initially conducted by four final year undergraduate students under the weekly supervision of an experienced academic. With greater research experience, the researchers would have been more efficient in their work but the adoption of the MLR methodology gave structure and rigour to the work.

Although COVID-19 was only declared a global health emergency in March 2020, there is already a vast amount of published material available. A search in google scholar for the terms *Covid-19* and *Work* returns >3 million results which is far too many to attempt to include in any single human-led research effort. For this reason, this work narrowed its focus to just four themes, Remote work, Team management, Work/Life balance, and Technology/Software Engineering Methods. All four of these themes are presented from a general working context and also from the perspective of software engineering work. Other themes could have been explored and greater numbers of works could have been included in the analysis, and this would have improved the breadth and depth of research and associated understanding. Time limitations, however, constrained the scope and depth of the review.

5 Conclusion

This research has uncovered a beguiling spectrum of agendas, behaviours and preferences in evidence in the attitude of software developers to WFH. As an emergency response, WFH was unavoidable for many as the international community grappled to contain the transmission of COVID-19. But this emergency has acted as a catalyst to experiment with highly distributed software engineering, with most developers based in their own home. What have we learned about software engineering WFH during the COVID-19 pandemic?

- WFH during a pandemic is a poor approximator to WFH in the absence of a pandemic. There are too many confounding and complicating factors to consider, including household health, employment and finances.
- WFH in response to a global pandemic is crisis management, it did not involve the levels of careful planning that would ordinarily smooth the transition to a different working paradigm. In some cases, the lack of planning and need to just survive and maintain operations allowed decisions to be made quickly and without over-analysis.
- There is a wide spectrum of developer experiences and attitudes towards WFH during the COVID-19 pandemic. Some report that they excel in their newfound flexibility, others are less ebullient.
- Some developers are ill-equipped personally and technologically for WFH during COVID-19. Issues can be as simple as poor broadband, and as complex and concerning as depression and isolation. Lack of appropriate hardware and work space (monitor(s) and peripherals such as mouse, keyboard, dedicated and appropriate desk) might affect productivity and mood.
- Some productivity gains have been reported but this could be a temporary bounce fuelled by complex factors, ranging from fear of unemployment to adrenaline-led performance in response to an emergency.
- For some developers, a performance gain might be a real phenomenon, and it may be sustainable in a full time WFH arrangement, but too little is known at this point and sustainability concerns have also been expressed.

Ask any gambler and you will soon discover that predicting the future is beset with risk. Integrating the learnings of this research, we therefore do not *predict* the following post-pandemic outcomes for software engineering work but rather suggest that they appear *plausible* at this time:

- Once personal travel constraints are removed, it is likely that many developers will want to meet with their colleagues and will rediscover the enjoyment and fulfilment that can bring.
- Some (many?) developers are not likely to want to return full time to commuting to work and attending a central office every day.
- Special provisions must be imagined and implemented to support onboarding, business expansion and basic business viability.
- Developers can be productive when largely WFH, perhaps even very productive, especially post pandemic restrictions when they can have greater free space and less noise in their dwellings, and more opportunity to socialise with colleagues.

- It will be a very challenging time for employers and those responsible for leading software teams. There is little wisdom to forcing employees to attend a central office and resent doing so (even less again if rivals are offering improved WFH arrangements); but it would also be unwise to fail to attend to the social fabric of software teams as without it, team communication and trust will decline; that would be an undesirable outcome for all stakeholders.
- Raising and sustaining productivity when WFM may involve more widespread adoption of Virtual Reality and Augmented Reality technologies [54, 55], and measurement of social productivity might need to be revisited or reinforced [56].
- Hybrid WFH and not-WFH work models will emerge. We can expect these to offer satisfactory levels of both social engagement and employee flexibility. We might expect to hear language such as: “we are a 90(WFH) : 10(NWFH) company” or “an 80:20 organisation” or “a 40:60 firm”. WFH : NWFH could come to be colloquially termed *HNH* (Home : Not Home) or some other easily verbalised term. Note that the Not Home part means precisely that, *not home*. Some team meetings could be held in locations other than a central office and there could be efficiencies to be gained from doing so.
- Highly distributed software teams seem suited to self-organisation and distributed systems architectures as these arrangements natively promote team and work distribution. This could result in software architectural transformation for some companies, and could result in increased interest in microservices architectures [57] and serverless cloud computing provisioning models [58].
- Developers must be realistic about their role in supporting teams and companies. It would be wrong for one individual to attempt to bend the organisation of entire teams around their private schedules. Work is work, and teamwork requires discipline and respect, and fairness of contribution. Meetings should start on time, they should finish on time, and they should achieve their objectives. Committed deliverables should tend towards being delivered at their committed time and at high quality. Companies will need to carefully monitor the participation and outputs of teams and individuals, human nature being what it is, some individuals will not embrace the flexibility of *HNH* in a mature fashion.

Software engineering is a complex undertaking [59] that should take account of various situational context considerations [60]. Roles such as *Software Engineer* and *Software Tester* have been evolving over time in response to changing contexts [61, 62]. The onset of COVID-19 related restrictions has brought about a sudden and highly disruptive change in context and to work patterns for many workers. Software developers have known for some time that WFH is possible, and some had already embraced WFH long before the COVID-19 outbreak. COVID-19 related work disruption has demonstrated that widespread and predominant WFH is certainly possible for the software engineering sector. It is difficult to envision a wholesale return to pre-COVID-19 software engineering work arrangements, developers would likely resist such a move and employers need to be alert to those sensitivities. There is a bumpy road ahead, a lot of work policies to be crafted, and ceremonies and communication constructs to reimaged. But it can be an exciting and worthwhile trip, with significant benefits for developers, their managers, and their employers.

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6 References

1. Béland, L.P., Brodeur, A., Wright, T.: The Short-Term Economic Consequences of Covid-19: Exposure to Disease, Remote Work and Government Response. Social Science Research Network, Rochester, NY (2020).
2. Donnelly, N., Proctor-Thomson, S.B.: Disrupted work: home-based teleworking (HbTW) in the aftermath of a natural disaster. *New Technol. Work Employ.* 30, 47–61 (2015). <https://doi.org/10.1111/ntwe.12040>.
3. Ralph, P., Baltes, S., Adisaputri, G., Torkar, R., Kovalenko, V., Kalinowski, M., Novielli, N., Yoo, S., Devroey, X., Tan, X., Zhou, M., Turhan, B., Hoda, R., Hata, H., Robles, G., Milani Fard, A., Alkadhi, R.: Pandemic programming. *Empir. Softw. Eng.* 25, 4927–4961 (2020). <https://doi.org/10.1007/s10664-020-09875-y>.
4. Buffer: State of Remote Work 2020, <https://lp.buffer.com/state-of-remote-work-2020>, (2020), last accessed 2021/02/15.
5. Russo, D., Hanel, P.P.H., Altnickel, S., van Berkel, N.: The Daily Life of Software Engineers during the COVID-19 Pandemic. *ArXiv210104363 Cs.* (2021).
6. Blake, K.D., Blendon, R.J., Viswanath, K.: Employment and Compliance with Pandemic Influenza Mitigation Recommendations. *Emerg. Infect. Dis.* 16, 212–218 (2010). <https://doi.org/10.3201/eid1602.090638>.
7. Smite, D., Moe, N.B., Klotins, E., Gonzalez-Huerta, J.: Work Patterns of Software Engineers in the Forced Working-From-Home Mode. *ArXiv210108315 Cs.* (2021).

8. Ford, D., Storey, M.-A., Zimmermann, T., Bird, C., Jaffe, S., Maddila, C., Butler, J.L., Houck, B., Nagappan, N.: A Tale of Two Cities: Software Developers Working from Home During the COVID-19 Pandemic. ArXiv200811147 Cs. (2020).
9. Russell, H., O'Connell, P.J., McGinnity, F.: The Impact of Flexible Working Arrangements on Work–Life Conflict and Work Pressure in Ireland. *Gend. Work Organ.* 16, 73–97 (2009). <https://doi.org/10.1111/j.1468-0432.2008.00431.x>.
10. Hyman, J., Baldry, C., Scholarios, D., Bunzel, D.: Work–Life Imbalance in Call Centres and Software Development. *Br. J. Ind. Relat.* 41, 215–239 (2003). <https://doi.org/10.1111/1467-8543.00270>.
11. Gartner: Gartner CFO Survey Reveals 74% Intend to Shift Some Employees to Remote Work Permanently, <https://www.gartner.com/en/newsroom/press-releases/2020-04-03-gartner-cfo-surey-reveals-74-percent-of-organizations-to-shift-some-employees-to-remote-work-permanently2>, (2020), last accessed 2021/02/16.
12. BBC: Coronavirus: Twitter allows staff to work from home “forever,” <https://www.bbc.com/news/technology-52628119>, (2020), last accessed 2021/03/04.
13. Otago, U.: Study investigates New Zealanders’ attitudes towards working from home, <https://www.otago.ac.nz/news/news/otago737417.html>, (2020), last accessed 2021/02/16.
14. Borden, J.H., Laura Casado, Tyler Sonnemaker, Taylor: 21 major companies that have announced employees can work remotely long-term, <https://www.businessinsider.com/companies-asking-employees-to-work-from-home-due-to-coronavirus-2020>, (2020), last accessed 2021/02/16.
15. Two Cheers for the Virtual Office - ProQuest, <https://search.proquest.com/openview/35bcb648356f8eece6a2726f4c6424e9/1?pq-origsite=gscholar&cbl=26142>, (1998), last accessed 2021/02/15.
16. Gupta, A.: Accelerating Remote Work After COVID-19, <https://www.thecgo.org/research/accelerating-remote-work-after-covid-19/>, (2020), last accessed 2021/03/05.
17. Mancl, D., Fraser, S.D.: COVID-19’s Influence on the Future of Agile. In: Paasivaara, M. and Kruchten, P. (eds.) *Agile Processes in Software Engineering and Extreme Programming – Workshops*. pp. 309–316. Springer International Publishing, Cham (2020). https://doi.org/10.1007/978-3-030-58858-8_32.
18. Ng, J.J., Navaretnam, S., Wei, J.L.Q.: Considerations for IT Management in a COVID-19 World. *IEEE Eng. Manag. Rev.* 48, 16–18 (2020). <https://doi.org/10.1109/EMR.2020.3014777>.
19. Waizenegger, L., McKenna, B., Cai, W., Bendz, T.: An affordance perspective of team collaboration and enforced working from home during COVID-19. *Eur. J. Inf. Syst.* 29, 429–442 (2020). <https://doi.org/10.1080/0960085X.2020.1800417>.
20. Johnson, S.D., Suriya, C., Yoon, S.W., Berrett, J.V., Fleur, J.L.: An overview of cooperative learning. In: In. pp. 31–44. Brookes Press (1994).
21. Miller, C., Rodeghero, P., Storey, M.-A., Ford, D., Zimmermann, T.: “How Was Your Weekend?” Software Development Teams Working From Home During COVID-19. ArXiv210105877 Cs. (2021).
22. Zoom, Microsoft Teams, and Slack Have Exploded Due to the COVID-19 Pandemic. Can They Hold onto This Growth? | GLG, <https://glginsights.com/articles/zoom-microsoft-teams-and-slack-have-exploded-due-to-the-covid-19-pandemic-can-they-hold-onto-this-growth/>, (2020), last accessed 2021/02/17.
23. Leonardi, P.M.: COVID-19 and the New Technologies of Organizing: Digital Exhaust, Digital Footprints, and Artificial Intelligence in the Wake of Remote Work. *J. Manag. Stud.* (2020). <https://doi.org/10.1111/joms.12648>.
24. Richter, A.: Locked-down digital work. *Int. J. Inf. Manag.* 55, 102157 (2020). <https://doi.org/10.1016/j.ijinfomgt.2020.102157>.
25. Tarki, A., Sanandaji, T., Francis, B.: Why Hiring During Covid Is Different Than in Previous Downturns, <https://hbr.org/2020/10/why-hiring-during-covid-is-different-than-in-previous-downturns>, (2020).
26. Bayern, M.: The most in demand jobs and skills as a result of COVID-19, <https://www.techrepublic.com/article/the-most-in-demand-jobs-and-skills-as-a-result-of-covid-19/>, (2020), last accessed 2021/02/17.
27. Gresing-Pophal, L.: Best Practices for Hiring During COVID-19 (and Beyond), <https://hrdailyadvisor.blr.com/2020/09/09/best-practices-for-hiring-during-covid-19-and-beyond/>, (2020), last accessed 2021/02/17.
28. Biro, M.: Hiring During the COVID-19 Crisis: 6 Best Practices, <https://www.indeed.com/lead/hiring-during-pandemic-best-practices>, (2020), last accessed 2021/02/17.
29. Begel, A., Hemphill, L.: Not Seen and Not Heard. Microsoft Research (2011).
30. Rodeghero, P., Zimmermann, T., Houck, B., Ford, D.: Please Turn Your Cameras On: Remote Onboarding of Software Developers during a Pandemic. ArXiv201108130 Cs. (2020).
31. Hyacinth, B.: Employees don’t leave Companies, they leave Managers, <https://www.linkedin.com/pulse/employees-dont-leave-companies-managers-brigitte-hyacinth>, (2017), last accessed 2021/02/17.
32. Harter, J., Adkins A.: Employees Want a Lot More From Their Managers, <https://www.gallup.com/workplace/236570/employees-lot-managers.aspx>, (2015), last accessed 2021/02/17.
33. Spurk, D., Straub, C.: Flexible employment relationships and careers in times of the COVID-19 pandemic. *J. Vocat. Behav.* 119, 103435 (2020). <https://doi.org/10.1016/j.jvb.2020.103435>.
34. Forsgren, N.: Octoverse spotlight: An analysis of developer productivity, work cadence, and collaboration in the early days of COVID-19, <https://github.blog/2020-05-06-octoverse-spotlight-an-analysis-of-developer-productivity-work-cadence-and-collaboration-in-the-early-days-of-covid-19/>, (2020), last accessed 2021/02/17.
35. Toscano, F., Zappalà, S.: Social Isolation and Stress as Predictors of Productivity Perception and Remote Work Satisfaction during the COVID-19 Pandemic: The Role of Concern about the Virus in a Moderated Double Mediation. *Sustainability.* 12, 9804 (2020). <https://doi.org/10.3390/su12239804>.
36. Wright, S., Silard, A.: Unravelling the antecedents of loneliness in the workplace. *Hum. Relat.* 0018726720906013 (2020). <https://doi.org/10.1177/0018726720906013>.

37. Parthasarathy, S., Sridharan, C.: How the COVID-19 Pandemic Changed the Way IT Companies Work - IEEE Spectrum, <https://spectrum.ieee.org/at-work/tech-careers/how-the-covid19-pandemic-changed-the-way-it-companies-work>, (2021), last accessed 2021/02/17.
38. Butt, S.A., Misra, S., Anjum, M.W., Hassan, S.A.: Agile Project Development Issues During COVID-19. In: Przybyłek, A., Miler, J., Poth, A., and Riel, A. (eds.) *Lean and Agile Software Development*. pp. 59–70. Springer International Publishing, Cham (2021). https://doi.org/10.1007/978-3-030-67084-9_4.
39. Marek, K., Wińska, E., Dąbrowski, W.: The State of Agile Software Development Teams During the Covid-19 Pandemic. In: Przybyłek, A., Miler, J., Poth, A., and Riel, A. (eds.) *Lean and Agile Software Development*. pp. 24–39. Springer International Publishing, Cham (2021).
40. Neumann, M., Bogdanov, Y., Lier, M., Baumann, L.: The Sars-Cov-2 Pandemic and Agile Methodologies in Software Development: A Multiple Case Study in Germany. In: Przybyłek, A., Miler, J., Poth, A., and Riel, A. (eds.) *Lean and Agile Software Development*. pp. 40–58. Springer International Publishing, Cham (2021).
41. Bao, L., Li, T., Xia, X., Zhu, K., Li, H., Yang, X.: How does Working from Home Affect Developer Productivity? -- A Case Study of Baidu During COVID-19 Pandemic. *ArXiv200513167 Cs.* (2020).
42. Griffin, L.: Implementing Lean Principles in Scrum to Adapt to Remote Work in a Covid-19 Impacted Software Team. In: Przybyłek, A., Miler, J., Poth, A., and Riel, A. (eds.) *Lean and Agile Software Development*. pp. 177–184. Springer International Publishing, Cham (2021). https://doi.org/10.1007/978-3-030-67084-9_11.
43. Mancl, D., Fraser, S.D.: COVID-19's Influence on the Future of Agile. In: Paasivaara, M. and Kruchten, P. (eds.) *Agile Processes in Software Engineering and Extreme Programming – Workshops*. pp. 309–316. Springer International Publishing, Cham (2020). https://doi.org/10.1007/978-3-030-58858-8_32.
44. da Camara, R., Marinho, M., Sampaio, S., Cadete, S.: How do Agile Software Startups deal with uncertainties by Covid-19 pandemic? *Int. J. Softw. Eng. Appl.* 11, 15–34 (2020). <https://doi.org/10.5121/ijsea.2020.11402>.
45. Jasmine, C.A.: Impacts of COVID-19 on Company and Efforts to Support Organization Adaptability. *Social Science Research Network, Rochester, NY* (2020). <https://doi.org/10.2139/ssrn.3590726>.
46. Shalan, M.A., Algarni, M.A. (eds.): *Innovative and Agile Contracting for Digital Transformation and Industry 4.0: IGI Global* (2021). <https://doi.org/10.4018/978-1-7998-4501-0>.
47. Velavan, T.P., Meyer, C.G.: The COVID-19 epidemic. *Trop Med Int Health.* 25, 278–280 (2020). <https://doi.org/10.1111/tmi.13383>.
48. Russo, D., Hanel, P.H.P., Altnickel, S., van Berkel, N.: Predictors of Well-being and Productivity among Software Professionals during the COVID-19 Pandemic -- A Longitudinal Study. *arXiv:2007.12580 [cs]*. (2021).
49. Garousi, V., Felderer, M., Mäntylä, M.V.: Guidelines for including grey literature and conducting multivocal literature reviews in software engineering. *J. Inf. Softw. Technol.* 106, 101–121 (2019)
50. Maslach, C., & Leiter, M. P. (1997). *The truth about burnout: How organizations cause personal stress and what to do about it*. San Francisco, CA: Jossey-Bass.
51. P. Kruchten, R. L. Nord and I. Ozkaya, "Technical Debt: From Metaphor to Theory and Practice," in *IEEE Software*, vol. 29, no. 6, pp. 18-21, Nov.-Dec. 2012, doi: 10.1109/MS.2012.167.
52. Dirks, K.T. and Ferrin, D.L., "The Role of Trust in Organizational Settings," *Organization Science* 2001 12:4, 50-467
53. Government of Ireland, "Tánaiste signs Code of Practice on Right to Disconnect," <https://enterprise.gov.ie/en/News-And-Events/Department-News/2021/April/01042021.html>, last accessed 2021/04/09.
54. Nazligul, M.D et al.: Overcoming Public Speaking Anxiety of Software Engineers using Virtual Reality Exposure Therapy. In: *Proceedings of the 24th European and Asian Conference on Systems, Software and Services Process Improvement (EuroSPI 2017)*, pp.191-202, 5-8 September 2017, Ostrava, Czech Republic.
55. Gulec, U., Yilmaz, M., Isler, V., O'Connor, R.V., Clarke, P.: Adopting Augmented Reality as a Medium for Software Development Process Education. In *ACM proceedings of the International Conference of Software and System Processes (ICSSP 2018)*, Gothenburg, Sweden. 26-27 May 2018. pp.71-75.
56. Yilmaz, M., O'Connor, R.V., Clarke, P.: Effective Social Productivity Measurements during Software Development: An Empirical Study. *International Journal of Software Engineering and Knowledge Engineering (IJSEKE)*, 26(3), pp.457-490, DOI: 10.1142/S0218194016500194 (2016)
57. O'Connor, R.V., Elger, P., Clarke, P.: Continuous Software Engineering - A Microservices Architecture Perspective. *Journal of Software: Evolution and Process*, 29(11), 2017, pp.1-12.
58. Grogan, J et al.: A Multivocal Literature Review of Function-as-a-Service (FaaS) Infrastructures & Implications for Software Developers. In: *Proceedings of the 27th European and Asian Conference on Systems, Software and Services Process Improvement (EuroSPI 2020)*, Springer CCIS Vol. 1251, 9-11 September 2020, Dusseldorf, Germany.
59. Clarke, P., O'Connor, R.V., Leavy, B.: A Complexity Theory viewpoint on the Software Development Process and Situational Context. In: *proceedings of the International Conference on Software and Systems Process (ICSSP)*, Co-Located with the International Conference on Software Engineering (ICSE), pp. 86-90, (2016)
60. Clarke, P., O'Connor, R.V.: The situational factors that affect the software development process: Towards a comprehensive reference framework, *Information and Software Technology*, Vol. 54(5), May 2012, pp.433-447.
61. Meade E. et al.: The Changing Role of the Software Engineer. In: *Proceedings of the 26th European and Asian Conference on Systems, Software and Services Process Improvement (EuroSPI 2019)*, Springer CCIS Vol. 1060, pp.682-694, 18-20 September 2019, Edinburgh, Scotland.
62. Cunningham S. et al.: Software Testing: A Changing Career. In: *Proceedings of the 26th European and Asian Conference on Systems, Software and Services Process Improvement (EuroSPI 2019)*, Springer CCIS Vol. 1060, pp.731-742, 18-20 September 2019, Edinburgh, Scotland.
63. Tekin, N. et al.: Visualization, Monitoring and Control Techniques for Use in Scrum Software Development: An Analytic Hierarchy Process Approach. In: *Proceedings of the 27th European and Asian Conference on Systems, Software and Services Process Improvement (EuroSPI 2020)*, Springer CCIS Vol. 1251, 9-11 September 2020, Dusseldorf, Germany.