New technology and professional work

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Abstract

Until recently the main effect of technology on professional or knowledge-based work has been to augment and expand it, partly as described in Autor, Levy and Murnane's 2003 analysis. There are now increasingly instances of knowledge-based work being automated and substituted, developments that are more familiar from factory and basic administrative settings. Two widely-quoted studies, by Frey and Osborne (2013) and Susskind and Susskind (2015), point towards significant technology-driven job losses including in professional fields. Subsequent analyses indicate that while some occupations will disappear or be deskilled, others will be created. The argument made here is that the most significant effect will be occupational transformation, necessitating different types of skills in a net movement towards work that is more digitally-oriented but also complex, creative and value-based. These changes have implications that are already beginning to affect the way that professions are organised and how practitioners are educated and trained.

Keywords
Professions and technology, technology and work, Industry 4.0, Frey and Osborne, Susskind and Susskind

Introduction

A popular interpretation of emerging technological advances is to posit a "fourth industrial revolution" (Schwab 2016) or "second machine age" (Brynjolfsson and McAfee 2014). This can be seen as a step-change from the initial emergence of computerisation and automation, analogous to the impact on the water- and steam-powered industrial revolution of electrification and the internal combustion engine. As has happened with previous technological advances there is an expectation of widespread disruption to jobs, changes in the way that work is organised (e.g. Johannessen 2019), and in some quarters a revisitation of ideas such as the 'end of work' (Rifkin 1995).

A significant difference between the initial computer age and current advances is that the latter are expected to have a widespread impact on the nature of professional and knowledge-based work, and potentially on the organisation of professions themselves. The main effects of computerisation on professional jobs have so far been to enhance what practitioners do or make them more efficient, to enable new ways of working, and to create new fields of work associated with the technology itself. To date, large-scale disruption to employment has tended to occur in lower- to middle-skilled occupations, particularly in manufacturing and in basic administrative work, leaving professional work largely unaffected. Increasing technological capability is now predicted to encroach significantly on knowledge-based work, with consequences for professions, their organisation, and the education and training of practitioners (e.g. Susskind and Susskind 2015).

A difficulty with making predictions about the effects of technological advances is that they are dependent on assumptions about how technology can be transferred into the workplace (and used by the populace in general), the economics of technological substitution, choices made by actors from governments and multinational corporations through to individuals, and the way in which work and its organisation is able to evolve. There is a danger of descending into speculative futurology which can make for thought-provoking reading but is rarely a good basis for policy decisions or deciding on practical matters such as the design and content of professional courses. A common tendency ("Amara's law") has been to overestimate the effects of technological changes in the short term, but underestimate (and mispredict) them in the longer term.

The remainder of this paper examines current evidence and discussion on the impact of technology on work, and argues that while there will be implications for professions, making sense of these needs to consider more than the ability of emerging technologies to automate or substitute for tasks currently associated with professional occupations.

Technology and work: a summary

A widely-used model for conceptualising the effect of technology on work is that set out by Autor, Levy and Murnane (2003). These authors propose three principal effects of introducing new technology. Firstly, it can *enhance or augment* jobs, when it makes work more effective, efficient or less difficult, or enables tasks to be done that would otherwise be impossible, unsafe or uneconomic. Secondly, it can *automate* them, as has happened with much assembly-line work, removing or reducing the need for human input. Finally, it can enable them to be *substituted* by alternative means of achieving equivalent ends, as has happened with telephonists and typists. To apply their model, Autor and colleagues divide work into four types, namely routine manual (e.g. picking, sorting and other rule-based tasks), non-routine manual (such as driving and janitorial tasks), routine cognitive (e.g. book-keeping, filing and retrieval), and non-routine cognitive (activities that require the use of mental models and abstract thinking). They conclude that routine manual work is most susceptible to automation, and routine cognitive work to substitution. Technology tends to complement or augment non-routine cognitive work, while there is limited opportunity to substitute, automate or complement non-routine manual tasks.

Since Autor and colleagues' paper, advances in technologies such as artificial intelligence, machine learning, optics, and mobile robotics are making automation of increasingly non-routine manual tasks possible, as well as providing improved complementarity (for instance through the use of augmented reality and global positioning systems). In addition, some apparently non-routine cognitive activities, particularly those relating to analysis, diagnosis, and some types of research and drafting, now appear within the scope of automation or substitution (Brynjolfsson and McAfee 2011, Frey and Osborne 2013, Susskind and Susskind 2015, Casserta and Madsen 2019). In part, this is being made possible by focusing on what computers can do most effectively, such as processing vast amounts of information ("big data") or making precise measurements very quickly, rather than attempting to create algorithms that emulate how humans would go about a task (cf. Dreyfus and Dreyfus 1986). Nevertheless, most writers agree that there are limits to automation or substitution, both due to technological limitations or "bottlenecks" and in relation to social acceptability (e.g. Frey and Osborne 2013, Arntz, Gregory and Zierahn 2016). "Bottlenecks" occur where it is difficult or impossible to emulate or bypass human activity; Collins (2018) for instance discusses the limitations of computers in relation to social and contextual intelligence, and argues that a qualitative leap in machine learning is necessary before significant advances will be made in this area.

A more recent perspective on Autor and colleagues' model is provided by Nokelainen, Nevalainen and Niemi (2018), who modify their two dimensions to routine-complex and instrumental-meaningful. Routine instrumental work is most susceptible to technological automation or substitution. In the longer term, much complex instrumental work will increasingly also be displaced, as there is no additional value provided by having it performed by people and the only limitations are the capability and affordability of technology. Routine meaningful work (typically straightforward tasks where there is social value through human interaction) might ideally be done by people, but there may be economic pressures for automation. As Share and Pender (2018) indicate for social care, in some cases there can be benefits from tasks being done by machines; as an example, in the current coronavirus pandemic there are obvious benefits relating to infection control. In complex meaningful work, including "ethical decision-making, artistic, philosophical, therapeutic and caring tasks" (Nokelainen *et al.* 2018 p21), intrinsic value is provided by the activities being carried out by people, making them relatively resistant to automation or substitution; ultimately, the potential for displacement is not principally a factor of technological capability. Nokelainen and colleagues' conceptualisation has the benefit of building on the work of Autor and colleagues, while avoiding the latter's assumptions about technological limitations based on complexity; it offers a more resilient model in the light of subsequent discussions such as those of Susskind and Susskind (2015), Crookes and Conway (2018) and Blease and colleagues (2019).

One of the most widely-reported recent studies of the potential impact of technology on work is that of Frey and Osborne (2013, 2017). Their quantitative study examined 702 occupations from the United States occupational database O*NET. According to their analysis, 47% of US occupations do not contain significant technological bottlenecks and therefore are at risk of automation over the next decade or two, given foreseeable developments in technology. However, subsequent analyses of their approach suggest that it contains two significant flaws. Bonin, Gregory and Zierahn (2015) attempted to apply the same methodology in Germany, and Arntz and colleagues (2016) across the OECD countries. By taking a finer-grained approach which looked at tasks and activities within jobs, both groups concluded that while many jobs include automatable activities, the proportion of occupations that are likely to disappear is around 9%, rising to 12% in countries with a large manufacturing sector such as Germany. Not dissimilarly, McKinsey (2017) suggest that 60% of occupations have at least a third of their tasks capable of automation, but only 5% can be fully automated. However, a caveat is necessary in that all of these studies focus principally on activities that can be automated or directly substituted for. They pay less attention to wider-scale substitution, where activities that may themselves not be easily performed by technology—Susskind (2018) for instance gives the example of lawyers representing clients in court—nevertheless may be at least in part substituted by different, technology-facilitated approaches that achieve equivalent ends.

The second objection to using Frey and Osborne's conclusions as a prediction of labour market impact is that they treat occupations as fixed in the face of advancing technology (Frey and Osborne 2013 p39). This doesn't take account of the likelihood of new areas of work emerging (De Groen, Lenaerts, Bose and Paquier 2017); of jobs and occupations being transformed rather than eliminated (Bonin *et al.* 2015, Gifford and Houghton 2019); or substantial differences in the make-up of nominally the same occupation in different workplaces (Autor and Handel 2013). In addition to automation, substitution and complementarity, technology can also create work, as well as transforming it where workers take on different, hard-to-automate responsibilities and tasks (Bonin *et al.* 2015, CEDEFOP 2017). More subtly, the boundary between complementarity and substitution can be fuzzy, for instance, where efficiency is increased to the point where less workers are required, sometimes accompanied either by upskilling or deskilling of those who remain (Fischer and Pöhler 2018).

The most striking qualitative headline from the above is the extension of automation and substitution into areas of cognitive and complex manual work that have hitherto seemed immune to it. Quantitatively, however, the predictions are of a continuing hollowing-out of middle-level occupations, where more easily automatable and substitutable jobs in administration, manufacturing, construction and the like are lost, balanced by growth in professional and managerial work, personal service occupations, and non-routine but low-skilled and often temporary or on-demand manual and customer-facing work (among others Frontier Economics 2018). Predicting the long-term impact on the labour market is extremely difficult as it depends in addition to technological capability on factors such as how the returns to technological investment are distributed, the social, political and economic actions of decision-makers, and what new areas of work become necessary and valued. The current consensus is that predictions of “the end of work” are very wide of the mark, and while the “second machine age” will create significant disruption to jobs and to society more generally, its net quantitative effect is likely to be balanced with a mixture of job losses and gains (Autor 2015, Hislop, Coombs, Taneva and Barnard 2017). What does appear inevitable, however, is that this disruption will extend to professional occupations much more than has previously been the case, affecting the day-to-day work and skills of practitioners but also extending to the way that professions are conceptualised and organised.

The potential impact on professions

The idea of “a profession” is difficult to define precisely, as any characteristics that can be posited for professions are typically either found among at least some occupations that would not normally be regarded as such, or are lacking in some fields that are widely thought of as professions (Lester 2017). The best that can be done is usually to posit a few attributes that epitomise what is intended. At a theoretical level, expert knowledge, the exercise of independent thought, and commitment to the field in a way that extends beyond any employment or contractual relationship are fairly widely-applicable principles (Hoyle and John 1995). Practically, some form of self-organising structure is typically present, with criteria for becoming a member of the profession (in modern terms usually including attainment at degree level or above) and scope to eject members who practise incompetently or unethically (Belfall 1999). The purpose here is to focus on occupations that approximate to the above criteria as opposed to “higher-level” or knowledge-based work more generally, although parts of the discussion will have this wider relevance.

As noted in the previous section, the main effect to date of advancing technology on professions has been to complement and enhance work, as well as to create new fields relating to the technology and its application. Technology has typically made practitioners more efficient and better-informed, enabled them to carry out new tasks, increased communication and accountability, and in some cases increased their exposure to market forces and client or patient choice. Its structural effects have nevertheless tended to have been limited and evolutionary within professions themselves. It has had more effect on ancillary occupations, for instance, assistants who might have typed up practitioners’ reports, managed their appointments, researched and collated straightforward data, or organised documents for processing. New fields have typically been accommodated within existing ones (such as the various branches of engineering, or the library and information field), or created new professions that so far have formalised themselves to only a limited degree. Some of these newer fields, such as computer programming and software engineering, have evolved rapidly in parallel with the development of the technology, while others such as web design are partly rooted in technology and partly in pre-existing fields such as graphic design, communications and marketing. The structural effect on established professions has been minimal, and societal, economic and legislative pressures appear to have had greater effect in for instance the reform of the UK legal professions; the increasing diversity of professional entry-routes; the upgrading of nursing and social work to graduate professions; and the emergence of "splinter" and cross-professional groups such as family mediators, vocational rehabilitation practitioners and physician associates (Lester 2009, 2016).

The emergence of technologies that are able to automate, enable substitution of, or substantially reduce the time spent on even quite complex professional tasks is however likely to have a more direct impact on professional occupations, at least in the medium term. Susskind and Susskind (2015) are informative about the kinds of changes that are taking place and that *might* happen here. Their basic analysis accords with that set out in the previous section in that certain types of professional work will be capable of being performed more effectively by machines, including much analysis, diagnosis, and retrieval and assembly of data. The implication of this over time is that professional work will move away from the acquisition and distribution of knowledge, and focus on areas such as making interpretive and moral decisions that are less susceptible to technology. A second theme that they identify is the capacity of technology to empower consumers to access knowledge and make decisions that are commonly the preserve of professionals, potentially making available "professional" expertise at minimum cost. In the longer term, they envisage substantial erosion of knowledge-based work and consequent widespread technological unemployment, along with challenges both to individual professions and to the professional ideal of ethically responsible, self-regulating practitioners.

Susskind and Susskind's conclusions differ in some important ways from those presented by among others Bonin and colleagues (2015), Frontier Economics (2018), Hislop and colleagues (2017) and McKinsey (2017). In part this can be explained by their analysis being more conjectural and extending over a longer timescale (up to five decades rather than two), as well as its taking greater account of the potential that technology provides for substitution. Nevertheless they make assumptions that mean that their conclusions need to be treated with caution. They view professional work as essentially technical-rational, emphasising the application of expert knowledge to convergent matters, and they also place it in a transactional, market-driven context. While many professionals do focus on work that is transactional and technical-rational, this fails to recognise the importance or even presence of work that is creative, interpretive, concerned with divergent and value-based matters, and collaborative. They are also largely dismissive of professional ethics, suggesting that these can be substituted by organisational, contractual and market arrangements (Susskind and Susskind 2015 p233 *et seq.*). A result of framing work in this way is that aspects that are complex and meaningful or are more subject to technological bottlenecks are downplayed, leading to the potential for substitution or automation being overestimated. Secondly, and shared with Frey and Osborne's 2013 analysis, there is underestimation of the opportunities created by technology, both directly and by transforming jobs by removing tasks that are better-performed electronically. Even if highly knowledgeable workers become no longer essential for many technical-rational tasks, there is plenty of intellectually complex, creative and indeterminate or value-driven work that can be done, some of which is likely to become increasingly vital as rising populations, increasing demands for goods and services, and unanticipated events continue to create existential threats. A recent British study of the impact of artificial intelligence on work (Gifford and Houghton 2019) indicates that artificial intelligence systems are, at least at present, creating and expected to create more opportunities for work than they are replacing or rendering redundant. Again, social, political and economic decisions are likely to play at least as important a role here as are purely technological capacities for substitution or automation.

An example that illustrates the continuing need for human interpretation and decision-making is what has been described as the "black box" issue (e.g. Remus and Levy 2017, Casserta and Madsen 2019). This refers to situations where the logic used by computers in producing outputs or predictions is not transparent, enabling for instance harmful or unethical factors to become unintentionally embedded into decision-making or into the legal system. An example of this is provided by recruitment selection, where even highly complex algorithms that are set up with full awareness of discriminatory factors can nevertheless result in decisions that are biased against underrepresented groups (Bogen and Rieke, 2018). The problem is not that individual "black box" issues cannot be overcome, but that they can arise unpredictably and therefore require an ongoing need for human oversight. Collins (2018) points here to the danger of a "surrender to machines", accepting computer outputs as authoritative without considering the possibility of errors, misinterpretations and malfunctions.

On balance it is likely that a significant proportion of professional tasks will become susceptible to automation or substitution, and as Susskind and Susskind argue, some will be done more effectively, efficiently and consistently by machines. Areas such as medical diagnosis (Blease *et al.* 2019), legal drafting (Susskind and Susskind 2015), routine research and data analysis (Pandit, 2018), and the assembly and auditing of accounts (Conway 2018) are obvious examples, but in principle any activity that follows an operational logic is susceptible—over time, anything that can be described as "complex-but-routine," which may increasingly approximate to Nokelainen and colleagues' complex and instrumental work. This kind of work is likely to become increasingly commodified, with the likelihood of practitioners becoming displaced in one way or another. Displacement may be into standardised and increasingly price-sensitive work (the province of what Johannessen [2019] terms the "precariat") or out of the field altogether, but it can also involve movement into complex and meaningful activities which as suggested above are likely to become more necessary and critical. Overall, therefore, a gradual qualitative shift in professional work can be posited to activities that are complex and meaningful, typically employing creativity, contextual interpretation, value-based decisions, and interpersonal negotiation (e.g. Conway 2018, Valin 2018, Flood 2019). This accords with an increasing focus for professionals on the "swampy lowland" of divergent issues and wicked problems that are not subject to neat solutions (Schön 1983), with creative-interpretive activity (Lester 2017), and with relationships concerned with realisation (Schiff 1970) and co-creation (Reeves and Knell 2006). In common with what has been said above about work in general, the result is likely to be both job losses and gains, along with the deskilling of some professional work to technician-type or paraprofessional roles, and the upskilling of other aspects as the focus moves to consistently non-routine and complex-meaningful activities.

The effect of these trends on individual professions will be influenced by a range of factors. The obvious one is the proportion of the profession's mainstream work that is complex-but-routine. Where this is relatively large, other things being equal there will be a high degree of technological disruption as many activities become automated or substituted. Whether this results in job losses or widespread deskilling then depends on further factors; the most significant one is whether enough non-susceptible work can be substituted so that the net result is job transformation rather than job losses. In addition, there may be limits to acceptable technological decision-making in some fields due to safety or ethical concerns, as well as continued (or resurgent) markets for some personally-provided services analogous to the growth in interest in craft-produced goods and foods. Several scenarios then emerge. On a rough continuum, these start from (a) minimal impact because the profession's work is not widely susceptible to automation or substitution; (b) relatively straightforward transformation, where enough non-susceptible work emerges to accommodate the majority of practitioners, with or without significant reskilling; (c) major disruption, with a mix of transformation and job losses; and (d) atrophy, where there is no continuing outlet for the profession's skills and expertise in their current form. This is further complicated by the emergence of new fields, some fast-moving and ultimately at least partly substitutable (cf. the evolution of computer programming), which will interact with existing professions in potentially complex ways.

Professional organisation and education

The above analysis, even if not as extreme as Susskind and Susskind's conclusion, still suggests some far-reaching implications for how professions are organised and for the education and training of professionals.

A prominent theme in the discussions above is that some occupations will disappear, some will undergo transformation, and other new ones will appear. For professions, this creates structural pressures and suggests that some existing groupings will need to be rethought if they are not to become redundant. Professions define themselves in various ways; for some the idea of a body of knowledge is central, some newer groupings have coalesced around occupational functions, while a trend over the last two decades or so has been definition around what might be termed a body of practice. This latter is broader than the idea of a set of functions or skills, and encompasses underlying principles and how they are embodied in practices that can typically evolve and be applied across an indeterminate range of contexts, in what has been termed a "centre-outwards" perspective (Lester 2014, 2017). *Given the same level of occupational disruption*, functionally-defined professions are likely to be most vulnerable to change, while those that start from a body-of-practice perspective will be most resilient. Groups that are relatively specialised and have come into being or evolved to provide well-defined services are the most likely to become redundant, while those that take a broad view of their fields and can transcend occupational functions and bodies of detailed knowledge are potentially more resilient. Further factors include deskilling, in some fields making professional modes of organising less useful to practitioners and their clients or employers; the growth of new technology-oriented occupations that may be too dynamic to allow traditional forms of professionalisation to appear; and the evolution of relatively new fields, such as those concerned with the environment, with ethics, and with human-machine interaction, into clearer professional groupings (though not necessarily formal professions).

Implications for education and training are perhaps the most difficult to predict, as they are affected by all of the factors discussed above. There are some obvious implications in terms of the technology itself, so that existing practitioners will need to be increasingly technologically adept (including in fields where technology has to date played a limited role), including being able to work competently with related risk-related and ethical matters. As specific, detailed knowledge becomes easier to access via technology, continued movement is likely away from the learning of a "body of knowledge" as the foundation for professional practice and towards a concern more directly with practices (Boud 2016). Echoing a trend reported more than a decade ago (Lester 2009), increased emphasis will be needed on understanding the principles underlying the area of work in order to aid, among other things, knowing what knowledge and skills to acquire and apply, how to interpret information and develop practice in context, and how to interpret and maintain oversight of information and analyses provided by machines. This suggests a (continuing) shift away from purely technical-rational expertise towards creative-interpretive professionalism and critical judgement, with areas such as ethics, sustainability, interpersonal and intercultural skills becoming more important (Penprase 2018). On the other hand, care is needed to avoid losing the skills and expertise that enable practitioners to recognise problems and intervene effectively when technology malfunctions, is sabotaged, or produces suspect answers (Billett 2018).

A second major need is towards increased flexibility of professional development, parallel with the expected evolution of professional fields. This may point to more interprofessional courses, different pathways to specialism, and overall a greater range of routes to qualifying that are less predicated on teenage career choices or constrained by "silos" dictated by current professional boundaries. These directions are an extension of what is already happening, although route flexibility is likely to become more common and extend to more professions that is currently the case.

Alongside this, there are likely to be implications for early-career, work-based training. A common pattern in many professions is to serve a fairly loose form of apprenticeship as the final preparation to practise. In this model, the time taken up by training is often balanced by the novice practitioner undertaking tasks that are initially relatively routine, but are nevertheless necessary and contribute to the employer's business. As Susskind and Susskind

(2015) argue, not only is this generally inefficient as a training process, but if in future many of these tasks are automated or become unnecessary, work-based training will need to become more focussed, particularly where it is accompanied by commercial pressures to bring the novice practitioner up to speed more quickly. Studies by Eraut (2008) and Allen and colleagues (2015) among others point to practitioners needing creative-interpretive skills increasingly early in their careers, generating pressure for more expansive and effective initial training. Putting these factors together suggests that early-career training will need to be geared to developing deep insights and high-level practice relatively quickly. An emergent example is provided by degree- and master's-level apprenticeships in the UK, where academic and workplace learning are specified through an apprenticeship standard and delivered in a way that (at least in the best examples) is genuinely integrated rather than through simply running off- and on-job training in parallel (Kuczera and Field 2018, Lester and Bravenboer 2020).

Conclusion

The "fourth industrial revolution" or "second machine age" is widely predicted to have a significant effect on work, particularly as technology starts to automate or result in the substitution of more complex types of activity. On balance, current analyses suggest that this will result in job losses in some areas, broadly offset by the emergence of new occupations. More significant however is occupational transformation, with implications for both initial education and reskilling. Importantly, many professional occupations will be affected directly by automation and substitution, with human expertise becoming less essential for even some highly complex tasks. This does not however spell mass redundancy across these occupations, but it will see changes to the tasks, fundamental skills and modes of organising of practitioners.

An increasingly nimble response is likely to be needed from professional governing bodies, whether these are state-backed regulators or independent associations, and higher education institutions. The former to some extent hold the key to adaptability, as where professional boundaries and entry-routes are maintained too rigidly, practitioners can be inhibited from developing their roles in new directions and educational institutions from developing programmes that are capable of preparing practitioners for upcoming challenges. In the latter, there are some good examples of programmes and frameworks that support learning for the kind of creative-interpretive practice discussed above, but there are also programmes that assume a largely "business as usual" approach even in areas where there is a high likelihood of substantial change.

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References

Allen, H., Magnusson, C., Horton, K., Evans, K., Ball, E., Curtis, K. and Johnson, M. (2015). People, liminal spaces and experience: Understanding recontextualisation of knowledge for newly qualified nurses. *Nurse Education Today, 35*(2), 78-83. https://doi.org/10.1016/j.nedt.2014.10.018

Autor, D. (2015). Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives, 29*(3), 3-30. https://doi.org/10.1257/jep.29.3.3

Autor, D. and Handel, M. (2013). Putting Tasks to the test: Human capital, job tasks and wages. *Journal of Labor Economics, 31*(2), 59-96. https://doi.org/10.1086/669332

Autor, D., Levy, F. and Murnane, R. (2003). The skill content of recent technological change: An empirical exploration. *Quarterly Journal of Economics, 118*(4), 1279-1333. https://doi.org/10.1162/003355303322552801

Arntz, M., Gregory, T. and Zierahn, U. (2016). *The risk of automation for jobs in OECD countries*. Paris, France: OECD (Social, Employment and Migration Working Paper 189). Retrieved from https://www.oecd-ilibrary.org/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7.pdf?itemId=%2Fcontent%2Fpaper%2F5jlz9h56dvq7-enandmimeType=pdf

Belfall, D. (1999). *Creating value for members*. Toronto, ON: Canadian Society for Association Executives.

Billett, S. (2018). Accessing and securing conceptual and symbolic knowledge required for digital era work. In C. Harteis (Ed.), *The impact of digitalization in the workplace* (pp. 197-212). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-63257-5_13

Blease, C., Kaptchuk, T., Bernstein, M., Mandl, K., Halamka, J. and DesRoches, C. (2019). Artificial intelligence and the future of primary care: Exploratory qualitative study of UK General Practitioners' views. *Journal of Medical Internet Research, 21*(3), e12802. https://doi.org/10.2196/12802

Bogen, M. and Rieke, A. (2018). *Help wanted: An examination of hiring algorithms, equity and bias*. Washington, DC: Upturn.

Bonin, H., Gregory, T. and Zierahn, U. (2015). *Übertragung der studie von Frey/Osborne (2013) auf Deutschland*. Mannheim, Germany: Zentrum fur Europaische Wirtschaftsforschung.

Boud, D. (2016). Taking professional practice seriously: Implications for deliberate course design. In F. Trede and C. McEwen (Eds.), *Educating the deliberate professional: Preparing for future practices* (pp. 157-174). Dordrecht, The Netherlands: Springer. https://doi.org/10.1007/978-3-319-32958-1_11

Brynjolfsson, E. and McAfee, A. (2011). *Race against the machine*. Lexington, KY: Digital Frontier Press.

Brynjolfsson, E. and McAfee, A. (2014). *The Second Machine Age*. New York, NY: Norton.

Casserta, S. and Madsen, M. (2019). The legal profession in the era of digital capitalism: Disruption or new dawn? *Laws, 8*(1), 1-17. https://doi.org/10.3390/laws8010001

CEDEFOP (2017). *People, machines, robots and skills: CEDEFOP briefing note*. Thessaloniki, Greece: CEDEFOP. Retrieved from https://www.cedefop.europa.eu/en/publications-and-resources/publications/9121

Collins, H. (2018). *Artificional intelligence: Against humanity's surrender to computers*. Cambridge, United Kingdom: Polity.

Conway, E. (2018). The future of accountancy: Beyond the numbers. In L. Crookes and E. Conway (Eds.), *Technology challenges in accounting and finance* (pp. 187-196). Cham, Switzerland: Palgrave Macmillan. https://doi.org/10.1007/978-3-319-91113-7_10

Crookes, L. and Conway, E. (2018). Technology challenges in accountancy and finance. In L. Crookes and E. Conway (Eds.), *Technology challenges in accounting and finance* (pp. 61-84). Cham, Switzerland: Palgrave Macmillan. https://doi.org/10.1007/978-3-319-91113-7_4

De Groen, W., Lenaerts, K., Bose, R. and Paquier, F. (2017). *Impact of digitalisation and the on-demand economy on labour markets and the consequences for employment and industrial relations*. Brussels, Belgium: European Economic and Social Committee. https://doi.org/10.2139/ssrn.2730550

Dreyfus, H. and Dreyfus, S. (1986). *Mind over machine: The power of human intuition and expertise in the age of the computer*. Oxford, United Kingdom: Basil Blackwell.

Eraut, M. (2008). Learning from other people in the workplace. In K. Hall, P. Murphy and K. Soler (Eds.), *Pedagogy and Practice: Culture and identities* (pp. 40-57). London, United Kingdom: Sage.

Fischer, C. and Pöhler, A. (2018). Supporting the change to digitalized production environments through learning organization development. In C. Harteis (Ed.), *The impact of digitalization in the workplace* (pp. 141-160). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-63257-5_10

Flood, J. (2019). Legal professionals of the future. In M. DeStefano and G. Dobrauz-Saldapenna (Eds.), *New Suits: Appetite for disruption in the legal world* (pp. 115-130). Bern, Switzerland: Stampfli Verlag.

Frey, C. and Osborne, M. (2013). *The future of employment: How susceptible are jobs to computerization?* Oxford, United Kingdom: University of Oxford.

Frey, C. and Osborne, M. (2017). The future of employment: How susceptible are jobs to computerization? *Technological Forecasting and Social Change, 114*, 254-280. https://doi.org/10.1016/j.techfore.2016.08.019

Frontier Economics (2018). *The impact of artificial intelligence on work: An evidence review prepared for the Royal Society and the British Academy*. London, United Kingdom: Frontier Economics.

Gifford, J. and Houghton, E. (2019). *People and machines: From hype to reality*. London, United Kingdom: Chartered Institute of Personnel and Development.

Hislop, D., Coombs, C., Taneva, S. and Barnard, S. (2017). *The impact of artificial intelligence, robotics and automation on work*. London, United Kingdom: Chartered Institute of Personnel and Development.

Hoyle, E. and John, P. (1995). *Professional Knowledge and Professional Practice*. London, United Kingdom: Cassell.

Johannessen, A. (2019). *The workplace of the future*. Abingdon, United Kingdom: Routledge.

Kuczera, M. and Field, S. (2018). *Apprenticeship in England, United Kingdom.* Paris, France: OECD Publishing. https://doi.org/10.1787/9789264298507-en

Lester, S. (2009). Routes to qualified status: Practices and trends among UK professional bodies. *Studies in Higher Education*, *34*(2), 223-236. https://doi.org/10.1080/03075070802528296

Lester, S. (2014). Professional standards, competence and capability. *Higher Education, Skills and Work-based Learning, 4*(1), 31-43. https://doi.org/10.1108/HESWBL-04-2013-0005

Lester, S. (2016). The development of self-regulation in four UK professional communities. *Professions and Professionalism, 6*(1), 1-14.

Lester, S. (2017). Reconciling activity-based descriptions of competence with professional work. *Higher Education, Skills and Work-based Learning, 7*(4), 381-393. https://doi.org/10.1108/HESWBL-07-2017-0042

Lester, S. and Bravenboer, D. (2020). *Sustainable degree apprenticeships*. London, United Kingdom: Middlesex University.

McKinsey (2017). *A future that works: Automation, employment and productivity*. New York, NY: McKinsey Global Institute.

Nokelainen, P., Nevalainen, T. and Niemi, K. (2018). Mind or machine? Opportunities and limits of automation. In C. Harteis (Ed.), *The impact of digitalization in the workplace* (pp. 13-24). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-63257-5_2

Pandit, N. (2018). *Artificial intelligence and its impact on the legal profession and its regulatory framework*. Birmingham, United Kingdom: CEPLER (Working Paper 01/2019). Retrieved from http://epapers.bham.ac.uk/3263/

Penprase, B. (2018). The Fourth Industrial Revolution and Higher Education. In N. Gleason (Ed.), *Higher Education in the era of the Fourth Industrial Revolution* (pp. 207-229). Singapore: Palgrave Macmillan.

Reeves R. and Knell, J. (2006). Good work and professional work. In J. Craig (Ed.), *Production values: Futures for professionalism* (pp. 211-218)*.* London, United Kingdom: Demos.

Remus, D. and Levy, F. (2017). Can robots be lawyers? Computers, lawyers and the practice of law. *Georgetown Journal of Legal Ethics, 30*(3), 501-558.

Rifkin, J. (1995). *The end of work*. New York, NY: Putnam.

Schiff, S. (1970). Training the Professional. *University of Chicago Magazine 42*(4), 8-14.

Schön, D. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

Schwab, K. (2016). *The fourth industrial revolution*. Geneva, Switzerland: World Economic Forum.

Share, P. and Pender, J. (2018). Preparing for a Robot Future? Social professions, social robotics and the challenges ahead. *Irish Journal of Applied Social Studies, 18*(1), 4. Retrieved from https://arrow.dit.ie/ijass/vol18/iss1/4

Susskind, R. (2018). AI, work and ‘outcome thinking’. *British Academy Review,* Autumn, 30-31.

Susskind, R. and Susskind, D. (2015). *The future of the professions: How technology will transform the work of human experts*. Oxford, United Kingdom: Oxford University Press.

Valin, J. (2018). *Humans still needed: An analysis of skills and tools in public relations*. London, United Kingdom: Chartered Institute for Public Relations.