How ChatGPT shapes the future labour market situation of software engineers: A Finnish Delphi study

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ABSTRACT

ChatGPT is changing our working lives, conjuring visions of revolutionary shifts ahead. ChatGPT is a chatbot based on generative artificial intelligence, which can, e.g., write computer code. This article explores how it might shape the future labour market situation of software engineers. A Delphi study with 14 experts was conducted in Finland. The first round identified possible futures, and the second round assessed their probabilities. Five scenarios prevailed: the unlikely scenario that the status quo persists; the ambivalent scenario that ChatGPT can replace software engineers to a large extent; the likely scenario that computer departments in startups embrace ChatGPT; the likely scenario that ChatGPT use proliferates among software engineers to increase productivity; and the highly likely scenario that ChatGPT makes computer programming accessible to the masses. Findings contradict previous discussions that technological advancements might take over especially routine tasks. ChatGPT can also take over non-routine tasks. Moreover, findings underline that digitalisation does not only bring about a choice between upskilling and employability loss, but also a democratisation of knowledge and expertise. Software engineers and companies might use the findings as an impetus for upskilling, while universities might feel nudged to incorporate ChatGPT more strongly into their curricula.

1. Introduction

ChatGPT is currently heatedly debated in the public. Some portray it as a laughingstock, describing the sometimes-hilarious malfunctions it can produce. For example, ChatGPT version 3 became famous for declaring its love to its users and suggesting eloping with them (e.g., Corfield, 2023). However, others see it as a major advancement of technologies with wide societal implications. For example, Microsoft co-founder and billionaire Bill Gates equalled its impact to that of personal computers or the internet (Mollman, 2023). The different assessments emerge because ChatGPT is still developing. It has much potential, but also many challenges (Deng & Lin, 2022). At the time of writing, the summer of 2023, it is still unclear as to what level of quality and functionality ChatGPT can be developed in the future.

ChatGPT is an artificial intelligence (AI)-based chatbot developed by OpenAI (OpenAI, 2023). It can be operated with commands in natural language, bar any programming skills. Its output is also presented in natural language, in texts that sound as if they may have been written by a human. ChatGPT receives its information from the large amount of text that it was trained with. However, it cannot scrape new information from the internet (Deng & Lin, 2022; Wu et al., 2023). OpenAI launched ChatGPT to the public in November 2022, choosing version 3 for this launch (OpenAI, 2023). It followed up with the improved version GPT-4 in March 2023 (Wu et al., 2023). The texts generated by ChatGPT can be used for a sheer endless number of practical purposes, with some of them replacing texts

that would usually have been written by humans. For example, they can be marketing messages, newspaper contributions, university assignments or even computer code (Meade, 2023; Rivas & Zhao, 2023; Rudolph et al., 2023; Surameery & Shaktor, 2023).

The technical capabilities of ChatGPT will most likely interfere with current labour markets (Cwikla & Lindell, 2023). Futures studies have repeatedly suggested such an effect of AI (e.g., Gruetzemacher & Whittlestone, 2022; Makridakis, 2017). The life-course perspective specifies that the labour market changes stem from alterations to working careers. This perspective follows developments in human lives, such as the developments of working careers (Komp-Leukkunen, 2023). For example, where ChatGPT can produce specific texts quickly and cheaply, it might replace human workers that wrote these texts until now (Taecharungroj, 2023). As a result, working careers might come to a halt, with the workers having to change careers or exit the labour market. Another example, the texts produced by ChatGPT sometimes contain grave content-wise errors. Therefore, the new job activity of checking and correcting ChatGPT outputs will probably emerge (Goddard, 2023). Consequently, work tasks may change, and workers may need to retrain to adapt to the new job profiles. However, while the life-course perspective clearly indicates that changes for the working careers of software engineers lie ahead, it did not yet establish what these changes are. The reason is that ChatGPT is still a new technology, and the expected changes lie in the future. Thus, the life-course perspective calls for futures studies on this topic.

Unfortunately, previous findings on the effects of technological change on working careers cannot be directly transferred to the case of ChatGPT. The reason is that ChatGPT triggers shifts that turn our previous understanding of labour market effects of technological advancement on its head. Previously, technological advancements were expected to eliminate especially routine jobs, such as construction workers, factory workers and machine operators (Fernandez-Macias & Hurley, 2017; Frey & Osborne, 2017; Kurer & Gallego, 2019). However, ChatGPT may replace jobs with less routine tasks. Moreover, previously, technological advancement was expected to create jobs, especially in the information and communication technology (ICT) sector (World Economic Forum, 2023). However, ChatGPT may also replace jobs within the ICT sector. Because of these new kinds of effects, we cannot yet state how ChatGPT will affect the labour market situation of software engineers. The present study contributes to filling this gap in knowledge.

This study explores how ChatGPT may shape the future labour market situation of software engineers. Software engineers are those persons who develop, build, and maintain computer software (Wang, 2008). Their relationship with ChatGPT is ambivalent. On the one hand, they drive the development of technologies such as ChatGPT. On the other hand, ChatGPT is capable of taking over some of their tasks, thereby affecting the need for this occupation. This study investigates how ChatGPT may affect Finnish software engineers. Finland is one of the most advanced OECD countries in terms of the digitalisation of society (Organisation for Economic Co-operation and Development, 2019). As a result, comparatively many Finns work in the ICT sector. In 2022, eight per cent of the Finnish workforce were ICT specialists, which is the second highest share within the European Union (Eurostat, 2023). The Finnish government is trying to further enhance the digitalisation trend. Because of this goal, Finland is among the first European countries to take national action on the European Commission's Digital Decade initiative (Sitra, 2022). Against this background, it comes as no surprise that the Finnish government did not regulate ChatGPT until now. Other countries, such as Italy, decided to temporarily ban ChatGPT because of data and youth protection concerns (Simmons, 2023). Thus, Finland has a comparatively high number of software engineers, and these engineers have been confronted with ChatGPT since its launch. This situation makes Finland an ideal location for the study at hand.

This study answers two research questions. First, what are the possible occupational futures for software engineers, given the existence of ChatGPT? The answer to this question takes inventory of the possible future scenarios, as they are seen by experts. Second, how likely are these future scenarios? The answer to this question quantifies the experts' opinions on how realistic each of the scenarios appears at the moment. Thereby, it identifies probable scenarios (Komp-Leukkunen, 2020). To answer the research questions, a Delphi study with experts in the field of software engineering and ChatGPT is carried out. Findings indicate what labour market developments for software engineers may lie ahead of us. Software engineers, policymakers, companies and even universities can use these findings to take proactive action.

The remainder of the article is structured as follows: first, the labour market situation of software engineers is reviewed; then, the effects of ChatGPT on this labour market situation are discussed. Next, the methodology and findings are presented. Finally, the findings are discussed, and conclusions are drawn.

2. The labour market situation of software engineers

Software engineers play a pivotal role in the emerging digital economy. They lay the technical foundation for this economy, allowing businesses and societies to take steps towards digital interactions (Brynjolfsson & Kahin, 2000; Dorschel, 2022). Consequently, there is a high and still growing demand for software engineers across the globe (Chow, 2022; Nizami & Prazad, 2017). In Finland alone, 210,000 new jobs for software engineers are expected to emerge until 2030 (Smolander et al., 2023). The high demand for software engineers makes it comparatively easy for them to find a job and gives them comfortable salaries. This observation holds true for developed and developing countries (Dorschel, 2022; Upadhya, 2011). As a side effect, it also creates status inconsistency. Status inconsistency is a sociological concept describing how individuals can combine characteristics that bequest them different levels of social status at the same time (Wiedner, 2022). Software engineers experience such an inconsistency, because they have a social standing and income that would indicate a higher social status, whereas their educational level may indicate a lower social status. For the occupation of software engineering, skills and experience are more important than formal educational degrees. As a result, some software engineers have higher education, while others are autodidacts or learned through other means, for example, by attending boot camps (Burke et al., 2018; Marasco et al., 2022; Mead, 2009). This status inconsistency further underlines the unusual position of software engineers in modern societies.

The labour market careers of software engineers have a characteristic two-stage structure. Software engineers need to keep up with

technological developments. Like many individuals nowadays, they need to engage in life-long learning to ensure their skills do not become obsolete (Kim & Park, 2020). However, in contrast to other workers, they cannot postpone dealing with the rapid technological progress in their area of work or take a break from it (Rantanen & Komp-Leukkunen, 2023;Uden and Dix, 2004). As a result, their need for continued education sets in earlier than for other professions, starting already at their labour market entrance (Marshall, 2011). In other professions, this need is discussed further into the working career, especially for older workers (Komp-Leukkunen, 2023). The need for continuous learning can be taxing for software engineers, letting them consider professional changes or an early end to their working careers (Brooke, 2009; Marshall, 2011). As a result of these considerations, software engineers often switch out of engineering jobs into a management role in their 30s or 40s (Marshall, 2011). This switch allows them to continue working in the field they are familiar with while using their experiential knowledge. At the same time, it reduces the pressure on them to keep up to date with the details of technological progress at an in-depth level (Marshall, 2011). This circumstance shows that the careers of software engineers mould themselves around technological progress. Where rapid technological progress occurs, such as the launch of ChatGPT, we can also expect effects on the labour market situation of software engineers.

3. The work of software engineers and ChatGPT

The life-course perspective highlights that working careers change in line with technological change. Technological advancements alter the social context surrounding working careers. They create new opportunities and challenges that workers need to adapt to (Komp-Leukkunen, 2023). ChatGPT triggers such a shift in the social context affecting the working careers of software engineers. ChatGPT can set off a transformative digitalization, which modifies the working tasks of software engineers. Retraining might be necessary (Komp-Leukkunen et al., 2022). ChatGPT might also take over tasks that have until now been carried out by software engineers, thereby replacing them. The working careers of some software engineers might come to a halt (Taecharungroj, 2023). Finally, ChatGPT might create new work tasks, or even new professions. Thereby, new job profiles and work opportunities for software engineers might emerge (Goddard, 2023).

However, the life-course perspective warns against generalizing such developments across entire populations (Mayer, 2009). Not all software engineers will be affected by ChatGPT the same. While some might see their jobs change, others might be made redundant or find employment in newly emerging professions. Thus, we can expect ChatGPT to shift the labour market situation of software engineers in manifold ways at the same time. For example, younger software engineers will feel the effects especially in the way they enter the labour market, whereas more experienced software engineers will feel them more strongly in the way their work is organized. Another example, software engineers working as within IT departments of companies will experience the effects of ChatGPT especially through new work practices, whereas software engineers who founded startups may also experience them through the new business opportunities their create.

Although ChatGPT is still young, we can already now see a range of effects on the labour market situation of software engineers. First, ChatGPT can be used to troubleshoot programming errors. Where such errors occur, the code in question can be copied and pasted into ChatGPT with the request for help. ChatGPT can then spot possible error sources and make suggestions for improvements. As a result, the errors can be corrected (Surameery & Shaktor, 2023). This use of ChatGPT can help less-experienced software engineers write functioning code, and it can replace some of the peer-reviewing of code that would otherwise happen. Therefore, the productivity of younger software engineers could increase, and the workload on software engineers could decrease.

Second, ChatGPT itself can generate computer code. The instructions for writing such code can be given in natural language, meaning in free-form text like the one in this very article (Kashefi & Mukerji, 2023). The user just needs to find the correct prompts to steer ChatGPT in this code writing progress. This activity is called prompt engineering. While the first jobs as prompt engineers already emerged, some researchers wonder whether they will also disappear again, as the average user gains more experience and skills in prompting (Meyer et al., 2023). This use of ChatGPT suggests that some tasks of software engineers could possibly be taken over by laypersons or by individuals with limited programming skills. As a consequence, some jobs for software engineers might disappear with the advent of ChatGPT.

Third, ChatGPT can help individuals learn software engineering. It can act as such a tool in university education and in autodidactic activities (Merow et al., 2023; pp, 1309, 5783; Rahman & Watanobe, 2023). As a result of this use of ChatGPT, the level of software engineering knowledge may change. Depending on how students utilise ChatGPT, they may acquire more or less relevant knowledge than previous student cohorts during their studies. Moreover, individuals without any previous knowledge may be able to acquire software engineering skills more easily, possibly even all by themselves. As a result, software engineering could become democratised, being part of most people's skill sets. In such a situation, the demand for software engineers on the labour market may decrease.

These examples of possible applications of ChatGPT already indicate some of the changes that software engineers may experience in their labour market situation over the next years. While the emerging scientific discussions on ChatGPT already provide an indication of what some of these changes could be, they are by far not encompassing. The Delphi study described in this article provides a more detailed picture of what might lie ahead for software engineers.

4. Methodology

This article conducted a Delphi study to explore a topic about which still very little is known, namely how ChatGPT may share the labour market careers of software engineers. Delphi studies take a structured approach to collecting information from expert (Shelton et al., 2018). They let the experts themselves steer the cumulative knowledge building process and the data interpretation. The researcher takes on the role of a guide in the joint opinion building process. This distribution of tasks ensures that the experts' views are

accurately represented in the study's findings (Brady, 2015; Sossa et al., 2019). This approach is particularly helpful for topics about which little is known, such as the present one. Acknowledging the high uncertainty associated with this topic, this study followed a Delphi approach that focusses on arguments and strives to aggregate ideas (Hasson & Keeney, 2020; Niederberger & Spranger, 2020). This approach selects a lower number of experts with different backgrounds (Niederberger & Spranger, 2020). It collects information from them to map the different opinions and understand the reasoning behind them (Hasson & Keeney, 2020). The outcome is an overview of the landscape of arguments and thought. This outcome is particularly suitable for identifying scenarios, meaning possible and internally consistent future situations (Nowack et al., 2011). A set of scenarios can provide an overview of different ways how a situation might play out in the future. Therewith, it can show us different ways how software engineers might fare in the labour market when the use of ChatGPT becomes more common.

This study collected information from 14 experts in two rounds. Delphi studies have several rounds of data collection to share preliminary findings with the experts, which can react and improve these. Moreover, they maintain anonymity to ensure that the experts react to the content of the other experts' comments, instead of possibly being swayed by personal characteristics of the other experts (Rowe & Wright, 2001). The number of experts chosen is in line with previous studies, e.g. Gargon et al. (2019) and Taylor (2020). The experts were chosen to have different backgrounds (see Niederberger & Spranger, 2020). Among them were software engineers, a student representative for software engineering, owners and managers of companies using ChatGPT, consultants and business angels to companies working with ChatGPT, a representative of a startup association, and researchers and teachers in software engineering, who had been working with ChatGPT. All experts worked in Finland or at a Finnish company. Table 1 shows characteristics of the experts and the interviews.

Because little is known about the topic studied, the mode of selecting experts had to be adapted. Typically, Delphi methods would utilize a structured and pre-determined approach to selecting experts, e.g., via an expert matrix (Mauno et al., 2023; Rintamäki et al., 2016). However, this comparatively unexplored nature of the phenomenon studied rendered this approach not viable. Therefore, it was replaced with theoretical sampling. This sampling strategy relies on an iterative process of sampling and analysing. It carries out an analysis after each interview conducted, identifies the gaps in knowledge, and chooses the subsequent expert to always fill the biggest current gap in knowledge. The interview process stops when saturation was reached, meaning when additional interviews do not render new findings (Douglas, 2022; Glaser & Strauss, 2006). Thus, this approach draws on the data to decide who the most suitable experts for the study are. Supplementary Figure 1 provides an overview of the sampling strategy and the gaps in knowledge identified.

For the first round, expert interviews were conducted. The interviews were carried out in April and May, 2023. Complying with the General Data Protection Regulation of the European Union, informed consent was obtained in the beginning of the interviews. The experts were informed about the study purpose, the anonymity and confidentiality of the information collected, the voluntary nature of their participation, and their rights to refuse to answer questions, terminate the interview, and have all their data deleted. Moreover, they were given the option to ask questions. All interviews had the same structure. Initially, the experts were asked to introduce themselves and their work. Then, their experience with Artificial Intelligence in general and ChatGPT in particular was inquired about. In this context, they were asked about their views on possible future developments in the labour market situation of software engineers. Subsequently, findings from the previous interviews were discussed with them. The anonymity of the other experts can maintained in this context. Finally, they were invited to bring up any aspects of this topic that they considered relevant and that we had not previously discussed.

The interviews were only recorded after the experts agreed to such a recording. All experts agreed to be audio- (in face-to-face interviews) respectively video-recorded (in online interviews). The interviews lasted between 15 and 51 minutes. This duration is in line with other Delphi studies (e.g., Eccles et al., 2020). The interviews were transcribed, rendering a total of 122 pages of transcripts. Statements about the future were identified in the transcripts, and these statements were combined into scenarios of possible futures and into possible consequences of these scenarios (Nowack et al., 2011). The transcripts were analysed through qualitative content analysis, which lets categories and topics emerge from the text itself. It is particularly suitable for topics about which little

Table 1
Characteristics of the experts and the interviews.

Number	Occupation	Employer	Interview mode	Interview length (minutes)
1	Software engineer	A company in the well-being sector	In person	39
2	Lecturer in software engineering	A university	Online	22
3	Lecturer & head of an AI lab	A university of applied sciences	Online	43
4	Software engineer & startup founder	A company in the pedagogics sector	Online	40
5	Software engineer & CEO	Several companies using AI	Online	39
6	Researcher studying AI	A university	Online	50
7	Co-founder of a company	A company consulting on AI	In person	39 (interview together with no. 8)
8	Co-founder of a company	A company consulting on AI	In person	39 (interview together with no. 7)
9	Student representative in software engineering	A university	In person	15
10	Head of an association	An association representing startups	Online	51
11	Software engineer, startup founder	A startup & the company funding ChatGPT	Online	46
12	Software engineer	An IT consulting company	Online	46
13	Professional speaker & Business Angel	Self-employed	Online	42
14	Cyber security expert	Self-employed	Online	41

scientific knowledge exists, such as the study topic at hand. For the analysis, the following steps were taken: (a) an identification of all interview sections relating to the future labour market situation of software engineers, (b) an identification of the topics addressed in each section, (c) a grouping of sections with similar topics, and (d) a summary of the groupings in the form of a scenario and its consequences (Mayring, 2015).

In the second round, an online survey was conducted among the experts. This survey asked about the scenarios and consequences identified after the first round. Only the content of the scenarios and consequences was presented in the survey, while maintaining the anonymity of the experts. The survey questionnaire was structured around the five scenarios of possible futures identified. Each of these scenarios was presented in the same way: first, the scenario was described, and the respondents used a sliding scale from 'very likely' to 'very unlikely' to rate how likely they considered it to be. Then, three possible consequences of the scenario were listed, and the respondents rated the likeliness of each scenario on a Likert scale, ranging from 'very likely' to 'very unlikely'. The survey was fielded to the experts in June 2023. The experts had already been informed about this survey during their initial interview. Nine of the experts participated in it (response rate 64%). This response rate is in line with that of previous Delphi studies (Boel et al., 2021; Gargon et al., 2019). The survey answers were analysed through descriptive statistics.

5. Results

Five scenarios of possible futures were identified. These scenarios cover the range of possible future developments, from a lack of change to a fundamental shift with far-reaching consequences. The scenarios are: (1) A maintenance of the status quo; (2) Advancements in learning and teaching thanks to ChatGPT; (3) An integration of ChatGPT into startups; (4) An increase in the productivity of software engineers; and (5) ChatGPT taking over the jobs of software engineers. Supplementary Table 1 shows which experts mentioned each of these scenarios. It reveals that some scenarios were more obvious than others. The scenario suggesting an increase in the productivity of software engineers came to the minds of all experts, and the one suggesting advancements in learning and teaching was mentioned by half of the experts. The other scenarios were mentioned in fewer expert interviews. Figs. 1 and 2 illustrate the content of the scenarios. Fig. 1 shows how far in the future they are positioned, and how likely they are considered to be. Fig. 2 lists the possible consequences of each scenario, showing how likely these consequences are considered to be. The scenarios and their possible consequences are described below in sequence.

The first scenario describes a situation in which the status quo is largely maintained in the future. It postulates the following: 'ChatGPT cannot be improved anymore. It already reached its technical limits. Strict EU regulations hinder its use to ensure data security. Companies forbid their employees to use it because of concerns about trade secrets and intellectual property rights.' Thus, this scenario captures concerns about technological limitations and security. It raises the question whether ChatGPT can live up to the hype around it, suggesting that its potentials and impacts might be overrated. However, it also acknowledges that technological progress cannot be undone. However, regulations may be needed to let ChatGPT harmonise with extant societal structures. This scenario is placed in the immediate future, and little is needed to achieve it. ChatGPT's current state is considered final, and we would only need to
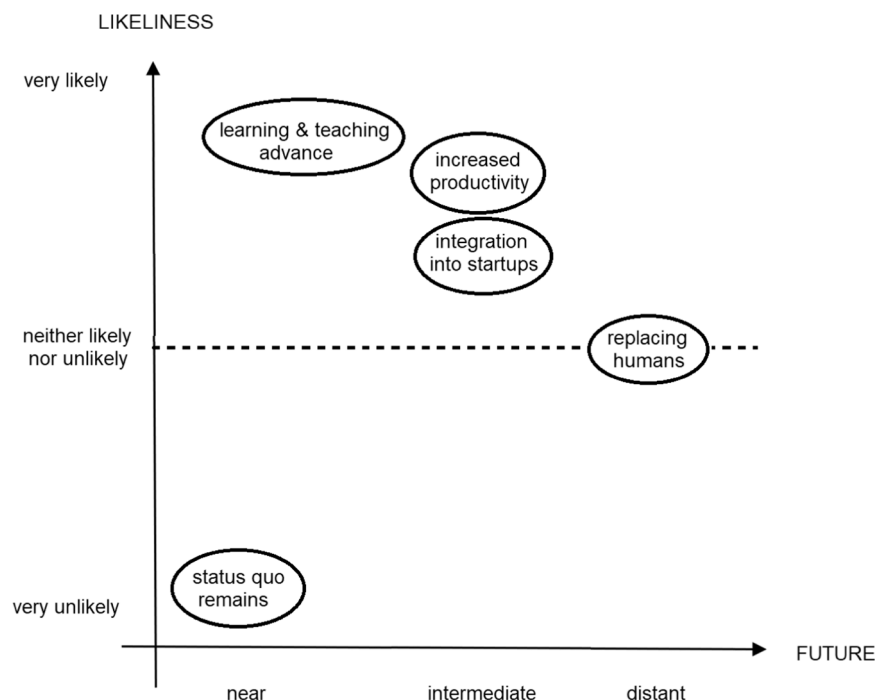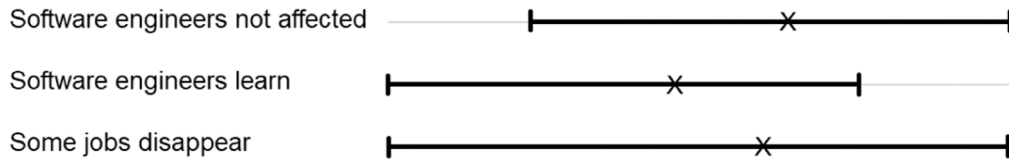

Fig. 1. Scenarios positioned within the dimensions of likeliness and future.
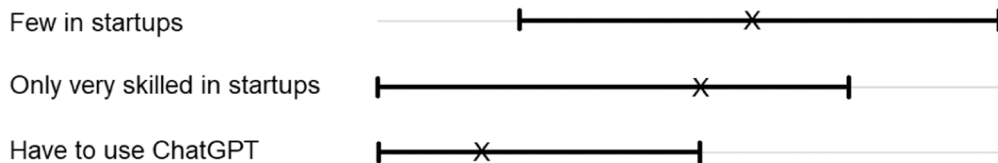
STATUS QUO REMAINS

Software engineers not affected

Software engineers learn

Some jobs disappear

LEARNING & TEACHING ADVANCE

Some jobs disappear

Solve complex problems

Software engineers manage

INTEGRATION INTO STARTUPS

Few in startups

Only very skilled in startups

Have to use ChatGPT

INCREASED PRODUCTIVITY

Some jobs disappear

Have to use ChatGPT

Only very skilled employed

REPLACING HUMANS

IT departments replaced

Only very skilled employed

Struggle to enter work

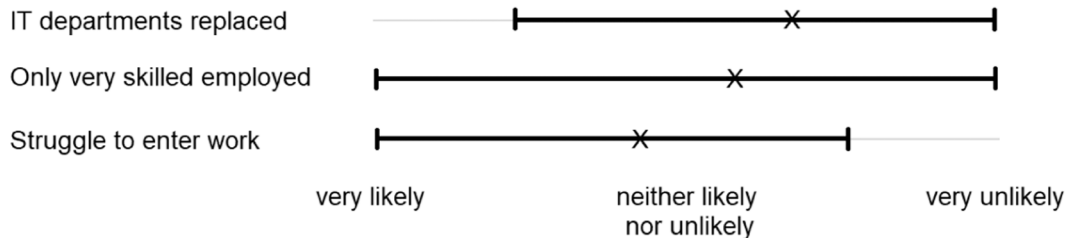very likely   neither likely nor unlikely   very unlikely

Fig. 2. Scenario and their consequences, with their likeliness. Notes: 'X' denotes the mean; a horizontal line denotes the range of answer categories chosen.

acknowledge this. Overall, the respondents considered this scenario unlikely. As possible consequences of this scenario, they discussed 'Software engineers are not affected at all', 'Software engineers need to learn new skills' and 'Some jobs for software engineers disappear'. However, they were undecided about all of these consequences, rating all of them around the neutral middle point "neither likely not unlikely". This rating reflects their overall assessment that the scenario can probably be disregarded.

The second scenario focuses on the use of ChatGPT for teaching and learning. It suggests the following: 'ChatGPT is taught at schools and universities. Everybody knows how to use it. With the help of ChatGPT, everybody can do some programming. Software

engineers are not needed anymore for simple programming tasks.' This scenario draws on suggestions that ChatGPT might lead to a democratisation of programming, giving everybody the option of becoming somewhat of a programmer. Consequently, computer engineers would lose some of their specialist status, becoming merely more skilled programmers than the bulk of less skilled programmers around them. This scenario is placed in the near future, building on developments that were already visible at the time of the interviews. The respondents described the developments they had observed and drew conclusions on where they might lead. The respondents agreed that such a scenario is very likely – viewing it as the most likely of all the scenarios discussed. In a similar vein, they agreed on the consequences of this scenario. The three consequences discussed were 'Some jobs for software engineers disappear', 'Software engineers focus on solving complex problems' and 'Software engineers do more management tasks'. The first two consequences were rated between likely and very likely, whereas the latter one was rated at the neutral middle point.

The third scenario centres on changes within startup companies. It reads as follows: 'Startups use ChatGPT to build their internet presence without software engineers. They also use it to develop a minimum viable product faster. As a result, they operate with fewer software engineers than before. They save money and scale up faster. The threshold for founding a startup sinks, and more startups are founded.' Thus, this scenario looks into a particular type of company, in which the effects of ChatGPT may be particularly extensive, welcome and early. This scenario is placed in the intermediate future. It was derived from strategic and logical analyses, rather then observations. The respondents considered the potentials of ChatGPT and concluded that startups would be an obvious beneficiary. For this scenario to come true, startups would need to do the same strategic and local analyses, and then act on them. The respondents considered such analyses and actions a hallmark of startups, and therefore expected them to already take place. Because startups usually are early adopters and risk-takers, the respondents expected them to start using ChatGPT immediately. The respondents considered this scenario likely to come about. However, they less sure about its consequences. The consequences discussed were: 'Few software engineers work in startups', 'Only very skilled software engineers work in startups' and 'Software engineers working in startups have to use ChatGPT'. The respondents were ambivalent about the first two consequences, choosing the neutral middle point for them. However, they were more convinced of the last consequence, suggesting that it was between likely and very likely to occur.

The fourth scenario shifts the focus to the daily work tasks of software engineers. It claims that 'Software engineers are skilled at using ChatGPT. They do all routine programming with ChatGPT. They spend most of their time on complex tasks and legacy code. Companies expect them to use ChatGPT to increase productivity and gain a competitive advantage'. Therewith, this scenario paints a picture of software engineers and companies embracing ChatGPT and reaping benefits from it. Issues of data security and technological limitations are set aside. This scenario is placed in the intermediate future. It was derived from economic considerations on business operations. The respondents considered the potentials of ChatGPT, and their business applications. They suggested that by default, companies would do the same. If any business opportunity arose from these considerations, companies would seize it. However, they also felt that ChatGPT would still need to further develop to become reliable enough for use in established companies. Only an improved version would let this scenario become reality. The respondents thought this scenario was likely to come about. They considered the following consequences: 'Some jobs for software engineers disappear', 'Software engineers have to use ChatGPT' and 'Only very skilled software engineers find employment'. The respondents agreed that the first two consequences were between likely and very likely. However, they disagreed on how likely the last consequence was and assigned it on average a neutral middle value.

The fifth scenario draws on ideas on how the technical potential of ChatGPT may unfold in the future. It states that 'ChatGPT improves further. It can autonomously carry out work tasks. So many apps are developed with ChatGPT that humans can no longer provide technical support and maintenance for all of them. ChatGPT provides the support and maintenance.' Thus, this scenario adopts an optimistic view on technological potentials, suggesting that considerable further developments of ChatGPT are possible. These developments can go so far as to replace humans in job tasks. This scenario is placed in the distant future. It requires ChatGPT to improve considerably, to a degree that had only been dreamed about at the time of the interview. Once such a radical technological improvement occurred, business processes could be adapted. Thus, no clear-cut path towards this scenario exists. Instead, far-reaching developments in technology and business would need to coincide for this scenario to become reality. Considering the speculative character of this scenario, it comes as no surprise that the respondents struggled to assess how likely it was. On average, they gave it a neutral assessment of "neither likely nor unlikely". They discussed the following consequences: 'Entire IT departments are replaced with ChatGPT', 'Only few very skilled software engineers find employment' and 'Junior software engineers struggle to enter the labour market'. However, they disagreed widely on how likely these consequences were, which results in an average around the neutral middle point for each consequence. This assessment underlines that the scenario is placed so far into the future that we can detect it in horizon scanning exercises, but it is still too early to assess it in greater detail.

6. Discussion

ChatGPT had been heatedly debated since its public launch in the end of 2022. Its innovative technological features are expected to create a sea change in information and communication technologies. As a consequence, it may also alter the fabric of societies and labour markets. This study explores how it might change the labour market situation of software engineers in the future.

The first research question was what possible occupational futures for software engineers exist, given the existence of ChatGPT. The findings identified five future scenarios. A first scenario describes the persistence of the status quo. The technological progress that already occurred would remain in place, but no further changes would occur. A second scenario describes enhanced learning of computer programming through ChatGPT. Schools, universities, and private individuals would embrace ChatGPT, using it to make programming feasible for everybody. As a result, software engineers would loose some of their expert status and job chances, while re-orienting themselves towards more complex job tasks. A third scenario outlines how software engineers working in startup will use ChatGPT for their work particularly early. Startup companies typically have a tight budget, and they welcome innovation to gain

business advantages and save money. To further their businesses, they might instruct the software engineers they employ to use ChatGPT particularly early and intensively. A fourth scenario suggests that software engineers in general become skilled and experienced ChatGPT users. All companies might decide to implement ChatGPT once the technology has developed further, hoping to increase productivity this way. As a result, some jobs for software engineers might disappear. Finally, a scenario describes how ChatGPT might further develop to replace humans. If it still makes considerable technological progress, it might at some point make entire IT departments redundant. The range of scenarios indicates that the consequences of ChatGPT still cannot precisely be pinpointed. The technology is still too new, and its potentials have still not been fully explored. The scenarios highlight that these consequences may unfold in numerous areas, at different times and to different effects.

The second research question inquired how likely the scenarios are. The scenario describing a maintenance of the status quo was considered highly unlikely. In contrast, the scenario of enhanced learning of computer programming through ChatGPT was considered very likely to come about in the near future. The third scenario outlining how startup companies might embrace ChatGPT was considered likely for the intermediate future. The fourth scenario suggesting increased productivity by using ChatGPT was also considered likely for the intermediate future. Finally, a scenario that ChatGPT might further develop to replace humans led proved difficult to assess. It was placed in the distant future, with the experts being undecided about its likeliness. These assessments underline that software engineers will most likely experience changes to their work. Some changes are already now becoming discernible, while others have the character of weak signals.

The findings have scientific implications. They give us a first glimpse of how ChatGPT might restructure the working careers and labour market situation of software engineers. Even though the impact of ChatGPT on labour market (e.g., Yu & Qi, 2004; Zarifhonarvar, 2023) has been studies, research concerning possible future changes in the career structures of software engineers is lacking. Such research is needed because software engineering is affected by ChatGPT, which is skilled at reviewing and creating code. The newness and rapid development of ChatGPT create uncertainties, making it difficult for experts to assess its possible future effects on the working careers of software engineers. Therefore, it comes as no surprise that many general effects of new technologies are also suggested for ChatGPT. Among these general effects are increased productivity, a possible job loss, and the need to retrain (Brynjolfsson et al., 2023; Frey & Osborne, 2017; World Economic Forum, 2023). Yet, two future scenarios stand out: the one concerning teaching and learning, and the one concerning startups. ChatGPT already now brought about visible changes in teaching and learning, which increase the overall level of digital skills among younger individuals. This development can bring about a democratisation of digital skills, letting individuals slip into the role of digital experts more quickly while stripping software engineers of some of their expert status. Therefore, future research on AI-induced labour market transformations also needs to reflect on the fluidity of the expert status. Moreover, ChatGPT attracts particular attention in the startup community, which thrives on quickly harnessing new business opportunities brought about by technological change (Cohen et al., 2017). As such, it seems likely to become one of the first place to utilize ChatGPT systematically and intensively for business purposes. Therefore, future research on the effects of ChatGPT on software engineers would benefit especially from studying startups. When conducting such studies, the life-course perspective may serve as a framework for guidance and reference. This perspective is starting to be used in studies on technology and working careers (see, e.g., (Komp-Leukkunen, 2023). Findings also advance the life-course perspective on jobs in the IT sector. Previous research showed that workers in this sector often decide on a career change based on their chronological age, preferring this change in their 30s or 40s (Marshall, 2011). This study highlights that such changes can also come about because of historical developments, such as radical technological changes. The life-course perspective describes this phenomenon as an embedding on life-courses in time and place (Komp-Leukkunen, 2023). Future research on working careers in the IT sector should pay special attention to this historical and geographical embedding of life-courses to better understand career turns.

Findings have practical implications. They outline what changes software engineers might expect in the future, thereby giving the software engineers, their employers, universities, and policymakers the chance to prepare. Software engineers intending to stay in their profession might want to use the insight gained to further familiarise themselves with ChatGPT and learn how to utilise it to increase their productivity (Özpolat et al., 2023). In contrast, those software engineers interested in a change in their tasks might alternatively want to develop their skills in management and solving complex tasks. They could use ChatGPT as an opportunity to gradually transition into a managerial role, as many software engineers do in their 30s or 40s (Marshall, 2011). The employers of software engineers might use the findings as an indication that a differentiated assessment of the effects of ChatGPT on the company's staff is needed. Employers need to consider who is affected, and in which way, in order to develop targeted human resources strategies. While employers in established companies might want to rely more heavily on training programmes, employers in startups might want to focus more strongly on reassessing how much staff they need to take their company to the growth phase (Kim et al., 2021; Lautenschläger, 2015). Universities educating software engineers should acknowledge that ChatGPT will be an important part of their students' future working life. As such, the students should learn how to use ChatGPT and to assess in which situations a use is advantageous and in which it can be problematic. Previous research showed that ChatGPT is not suitable for all students and situation, but that a considerable number of students does benefit from it (Ajlouni et al., 2023). Finally, policymakers might use the findings as an indication that there is more than one way to resolve the chronic shortage of software engineers. ChatGPT may not resolve the shortage, but it may at least reduce the number of software engineers needed. Together with the extant measures of educating more software engineers and recruiting such engineers from abroad, the deficit in supply can be more effectively addressed (Smolander et al., 2023). Therefore, policymakers may welcome ChatGPT as a contributor to managing the situation in the labour market in the ICT sector.

This study also has some limitations. First, it explores a very young technology, that had been launched only a year before the study took place. As a result, the labour market effects of this technology were just beginning to emerge, and the experts were still unsure on where these effects would lead. Consequently, they often made general statements about possible and probable futures. Such general

statements are suitable for getting a first impression. However, they are not suitable for detailed steering of labour market dynamics or business practices. Therefore, future research might want to replicate this study at a later point, when the consequences can be foreseen in greater clarity. Second, this study portrays the expectations at one point of time only, namely in the late spring of 2023. However, ChatGPT develops quickly, and it may make leaps in developments, as the changes from version 3 to version 4 documented. Consequently, the expectations towards ChatGPT may also change quickly. Therefore, this study should be seen as a portrayal of the situation at one point of historical time. The readers of this study should also consider the developments after this study was conducted when examining the relevance of ChatGPT for their current situation.

7. Conclusions

All in all, ChatGPT already started to change the way we work, and it has the potential to disrupt it to a larger extent. This is the first study to map how it might affect the labour market situation of software engineers. Like other workers, software engineers are expected to face the choice between upskilling or losing some of their employability – although to a much lesser degree. Unlike other workers, they are also expected to lose some of their expert status as ChatGPT brings about a democratisation of programming skills. Universities are expected to react early be incorporating ChatGPT in their teaching programmes. Startups are expected to react strongly by adapting the number of personnel. These changes are part of a bigger shift in how software engineers work, how companies operate, and how universities teach. The present study outlines the situation and expectations in early 2023, about one year after ChatGPT was launched. Therefore, it portrays the impressions and expectations that prevailed at that time. Future research needs to explore how the ChatGPT technology and expectations surrounding it developed after this time.

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Kathrin Komp-Leukkunen: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

No competing interests.

Data Availability

The data that has been used is confidential.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.futures.2024.103382.

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