

Bridging Gaps, Building Futures: Advancing Software Developer Diversity and Inclusion Through Future-Oriented Research

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ABSTRACT

Software systems are responsible for nearly all aspects of modern life and society. However, the demographics of software development teams that are tasked with designing and maintaining these software systems rarely match the demographics of users. As the landscape of software engineering (SE) evolves due to technological innovations, such as the rise of automated programming assistants powered by artificial intelligence (AI) and machine learning, more effort is needed to promote software developer diversity and inclusion (SDDI) to ensure inclusive work environments for development teams and usable software for diverse populations. To this end, we present insights from SE researchers and practitioners on challenges and solutions regarding diversity and inclusion in SE. Based on these findings, we share potential utopian and dystopian visions of the future and provide future research directions and implications for academia and industry to promote SDDI in the age of AI-driven SE.

CCS CONCEPTS

• **Software and its engineering** → **Programming teams**; • **Human-centered computing** → **Accessibility theory, concepts and paradigms**; • **Applied computing** → **Education**; • **Security and privacy** → **Human and societal aspects of security and privacy**.

KEYWORDS

Diversity and inclusion, metrics, methodologies, intersectionality, socioeconomics, knowledge transfer

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1 INTRODUCTION

Software systems are ubiquitous in society and impact nearly all aspects of modern life. Software engineering (SE), that is, the processes, methods, and tools to support the development and maintenance of software [49], is crucial for producing high-quality applications that impact human behavior, well-being, and decision-making. Recent innovations—such as the advent of large language models (LLMs) and machine learning-based systems—have transformed the software development landscape and introduced novel approaches to automate and support SE tasks [20, 66]. For example, GitHub

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states that, as of February 2023, their coding assistant Copilot is “behind an average of 46% of developers’ code across all programming languages.”¹

Despite recent technological innovations, SE is largely dependent on the efforts of software developers as “*significant human involvement and expertise*” [66, p. 13] are necessary to leverage LLM to automate tasks related to the design, implementation, testing, and maintenance of applications. However, the diversity and values of software development teams that design software systems often do not reflect the diversity and values of intended users, or, more broadly, our society. For example, in the 2022 Stack Overflow Developer Survey, approximately 92% of the respondents identified as male and 77% identified as White or European [46]. In contrast, the global population is approximately 50% male [23] and 16% White [57].

This “diversity crisis” [3] in software development can have major ramifications for people from underrepresented backgrounds. For example, research shows that most software lacks gender inclusivity, favoring the problem-solving processes of men [12]. Moreover, this crisis contributes to non-inclusive environments where minority developers are disadvantaged. For example, peer code reviews, where developers review code from contributors before merging into source code, are a common practice to improve software quality [40]. However, recent studies show that code contributions from programmers of non-White and non-male backgrounds receive more pushback [43] and higher rejection rates [44, 56].

Research reveals that diversity and inclusion enhance software development [22, 45]. For example, studies show that open source projects with diverse contributors are more productive [63], neuroinclusive teams are more productive than purely neurotypical teams [5], heterogeneous collaboration based on race and ethnicity leads to a higher number of contributions to open source projects [54], and working on gender-diverse teams improves attitudes towards women and improves decision-making and innovation [33]. However, a significant amount of work must be done to create inclusive work environments that lead to a more diverse community, which is building the software that is the foundation of our digital society.

To this end, this paper shares insights from SE researchers and practitioners on the challenges and opportunities with respect to diversity and inclusion. We begin by sketching four contrasting scenarios for SE in 2030, two outlining a utopian future, and two outlining a dystopian future. We then proceed to introduce four themes that guide the discussion in the remainder of this paper: methodologies and metrics, intersectionality, knowledge transfer, and socioeconomic understanding in SE. Based on these themes, we offer guidance for researchers to bridge the gaps in software developer diversity and inclusion (SDDI). Finally, we discuss how the rapid developments in artificial intelligence (AI) can challenge or support progress in SDDI, and how a carefully balanced use of AI is essential for building an inclusive future that avoids dystopian scenarios and gets as close as possible to a utopian future.

¹<https://github.com/blog/2023-02-14-github-copilot-now-has-a-better-ai-model-and-new-capabilities/>

2 RESEARCH PROCESS

The results presented in this paper originate in discussions during an academic meeting in June 2023.² This meeting brought together 23 software engineering researchers and practitioners from diverse backgrounds and career phases interested in fostering SDDI-related research. 18 workshop participants were actively conducting SE research at academic institutions from around the world, while five were researchers and/or developers at companies in industry. The workshop was organized in a hybrid format, with seven participants joining remotely.

To foster inclusive participation and generate a wide range of ideas from participants, we employed the liberating structure known as 1-2-4-ALL [38].³ Liberating structures are qualitative discussion techniques to support lively discussions and foster engagement in a group setting [1]. We utilized 1-2-4-ALL as a data collection method to allow self-reflection and collaborative discussion, building toward consensus or shared understanding among participants. Participants were divided into three breakout groups and tasked with producing one goal, two outcomes, and four themes related to challenges and opportunities to improve SDDI. The results of the breakout group discussions were brought to the broader group of participants to obtain feedback and reach agreement on a defined list of SDDI themes. The participants were then divided into groups according to the defined themes to further expand on the research challenges and solutions. After intensive discussions around the identified goals, outcomes, and themes in multiple group sessions, we developed a report⁴ summarizing the discussion for each theme.

In this paper, we expand on four of these themes with the aim of building a more coherent vision of future research directions for SDDI: methodologies and metrics, intersectionality, large-scale socioeconomic data, and knowledge transfer. These themes were chosen based on the timeliness, potential impact, and interest participants attributed to the themes. From each of the themes, we identified potential benefits and harms. In turn, the themes and related research literature guided us to form research goals for 2030.

3 FOUR SCENARIOS FOR 2030

In the following, we present two utopian scenarios, that is, scenarios “having the characteristics and organization of a perfect society”⁵ and two contrasting dystopian scenarios. These scenarios capture the future of software development work and the future of education, two areas that we, as SE researchers, can actively study and shape.

S1: Workplace Utopia: *Jamie works as a recently-graduated junior software engineer at an up-and-coming tech company. The company is at the forefront of inclusion, offering, e.g., flexible work arrangements that consider factors such as child care responsibilities, support for various career paths and the age of employees and applicants, and preferences concerning work and communication modes. These initiatives are paying off, as the company has successfully attracted a diverse workforce, leading*

²<https://shonan.nii.ac.jp/seminars/194>

³<https://www.liberatingstructures.com/1-1-2-4-all/>

⁴<https://shonan.nii.ac.jp/docs/No%20194.pdf>

⁵<https://dictionary.cambridge.org/dictionary/english/utopian>

to higher productivity, a welcoming and safe work environment, and more innovative and successful products. Despite coming from a minority group and being relatively junior, Jamie feels that the company provides a safe space for developing their career and competencies and invites them to participate in decision-making. For instance, the company offers automated tools to support various workflows, e.g., in code review and in programming, that allow Jamie to receive early feedback on their work, spot mistakes, and improve their skills without fear of discrimination. Similarly, the tools and practices at the company allow diverse teams to communicate effectively and positively. The company fosters a culture that encourages the active use and development of these tools for everyone's benefit, both within and beyond the company. In addition, the company carefully monitors existing diversity metrics and plans interventions based on them. Regular surveys help company leadership to consider employees' values in their strategic decisions.

Before graduation, Jamie studied at a university where they attended courses taught by Kris:

S2: Education Utopia: *Kris is a university-level educator in software engineering. Due to inclusive and equitable conditions at the university, students from varied backgrounds are enrolled in Kris' courses, contributing to a truly diverse and inclusive study experience. Although classes are large so that the university can cope with the continuing strong demand for software engineering professionals, technology advances and government incentives make it possible for Kris to provide targeted feedback to each and every student, regardless of diversity aspects such as gender, nationality, or age. Tools and indicators are also enabling automated feedback and coaching so that Kris and their staff can fully focus on providing the best possible learning experience. Finally, the assessment has changed from standardized and unified exams and assignments to a personalized form, tailored to suit each student's individual needs. In this environment, students feel safe to make mistakes and express themselves. In turn, this allows fruitful collaborations between students and staff.*

To contrast the experiences of Jamie and Kris, we outline a dystopian future in which Ash struggles in their workplace, and Moss struggles in their role as a student.

S3: Workplace Dystopia: *Ash has graduated from a prestigious university in their home country with a degree in software engineering. They are employed at a local IT company. The company provides software development services to large corporations in rich and highly developed countries. Due to the economic realities in their home country, Ash cannot make use of existing top-of-the-shelf tools, such as coding coaches or LLM-based code generation tools. This results in more manual work and less time to develop skills. Similarly, language barriers prevent them from learning and improving their skills in the same pace as similarly qualified graduates in richer and more developed countries, as existing tools cater only to English speakers. At Ash's employer, traditional gender role models and hierarchical structures persist and affect career progression chances. As a result, Ash feels that their chance to a successful career is relatively low due to factors outside of their control. An overall lack of awareness of diversity*

matters also affects the services provided by Ash's employer, as stereotypes and biases are ingrained in the labeled data.

Meanwhile, not only are workers such as Ash in emerging countries struggling, but education in rich and highly developed countries is also not what it used to be:

S4: Education Dystopia: *Moss is a student in software engineering at a local university. Many tasks and activities that used to involve human interaction have been replaced by automated tools. This has made education cheaper for the university. However, instead of lowering tuition fees, student numbers have increased dramatically, but staff have been reduced. As a result, Moss does not feel like they belong to the university, having almost no interaction with students and staff who come from a similar background as them. As someone who moved to the city for their studies, social integration has therefore been lacking. Instead, Moss feels that education could just as well be remote. Lecture topics and assignments lack personalization and typically cover generic and stereotypical examples.*

4 RESULTS: AVOIDING DYSTOPIA

In Section 3, we have outlined four scenarios on how SE industrial practice and higher education could look like in 2030. These scenarios do not have a direct connection to SE research. However, SE research can and should contribute to industrial practice and higher education in order to avoid the dystopian scenarios and instead achieve a future closer to the utopia described. To do so, we outline four orthogonal areas in which we believe SE research needs to evolve in the coming years.

In Scenario S1, several SDDI metrics guided the company's interventions toward a safer place for Jamie to develop their career. Similarly, Kris used various indicators in their educational setting in S2. If the university in Scenario S4 had monitored their students' experience and well-being using suitable metrics, they would have noticed the lack of belonging and feeling of inclusion among students such as Moss. These three scenarios motivate the use of diversity metrics that can be used by practitioners and educators to better understand diversity in their environment and make decisions based on them. SE research can contribute to this area by developing appropriate *Methodologies and Metrics*.

In Scenario S3, Ash's experiences conflated frustrations due to multiple diversity dimensions: socioeconomic background, language background, and gender. In contrast, various intersectional backgrounds were effectively supported in Scenario S2 through personalized learning, which has been shown to reduce educational inequality and foster inclusion for learners from diverse cultures [55]. These scenarios highlight the importance of developing a better understanding of *Intersectionality* in SE research, that is, when multiple diversity aspects overlap.

Both Scenarios S1 and S3 demonstrate how important it is that knowledge about SDDI be transferred to and from the SE field. For example, in Scenario S3, a lack of transfer of new ideas from outside means that traditional gender roles play a key role at the company, thus negatively impacting Ash's sense of belonging. In Scenario S1, Jamie and their employer thrive due to the adoption of diversity initiatives. As such, there needs to be an increased

push towards *Knowledge Transfer* between SE research, industry, education, government bodies, and societal groups.

Finally, industrial practice and higher education do not operate in isolation, but are embedded in the larger socioeconomic context. For example, in Scenarios S1 and S3, national circumstances had a decisive effect on the workplace situation—in opposite directions. Therefore, it is imperative to use better existing *Large-scale Socioeconomic Understandings* developed by other disciplines in SE research to provide more inclusive environments in the workplace and in higher education.

In the following subsections, we discuss these four themes in more depth and provide future-oriented research goals for each of them. These themes represent important research opportunities for the next five years to bridge the gaps in SDDI in practice.

4.1 Methodologies and Metrics

Methodologies and metrics are essential for scientific exploration and discovery [19]. Methodologies entail systematic research approaches for acquiring new knowledge through various research methods for data collection and analysis [67]. Metrics are used to quantify a characteristic of a real-world entity [9]. SE research, in particular, uses a variety of methods and metrics to provide empirical evidence to support software development processes and tools [24]. For example, previous work has used different techniques and measures to explore concepts related to SDDI, including surveys to understand developers' sense of belonging [59, 60], interviews to understand barriers for women in online programming communities [27], and studies mining GitHub repository to explore toxicity in open source software [41]. However, while all these examples are related to SDDI, an underlying theory describing how they connect is missing. For example, how do we investigate toxicity as a barrier to minorities' participation and belonging? "How" includes methods and metrics. Table 1 summarises potential benefits, harms and research directions for this theme.

The focus of this theme is not only on what has been published in the field of SE around diversity and inclusion and with which methods—but also a look at multiple domains, that is, SE, educational psychology, and management, to investigate more how insights from these fields could be incorporated into the methodologies and metrics used to research SDDI in SE. Additionally, investing in mixed-methods research [19], utilizing qualitative and quantitative data more efficiently, is an important future goal. *WEIGHTING*, *TIMING*, and *MIXING* are aspects that must be considered before planning mixed-methods SDDI research.

WEIGHTING refers to the priority given to qualitative and quantitative data in research [19]. The priority can be the same or favor one over another, depending on the researcher's goals and the audience. *TIMING* is about deciding whether to collect data sequentially in phases or concurrently [19]. In sequential data collection, either qualitative or quantitative data collection can occur first, depending on the research goal. Concurrent data collection involves simultaneously gathering data for qualitative and quantitative analyses, which can be interesting in time-sensitive projects where contacting participants multiple times for data collection is not feasible (e.g., single surveys with open and closed-ended questions) [58]. Previous SDDI mixed-methods research used both concurrent and sequential

mixed-methods research. Trinkenreich et al. [58] followed a concurrent mixed-methods research collecting data through a single survey to qualitatively uncover the challenges faced by women in software development teams and segment those challenges across demographics of age, caregiving responsibilities, marital status, and tenure. Examples of SDDI sequential mixed-methods research included surveys and mining software repositories studies in varying orders. Vasilescu et al. [63] started with a survey on perceptions of team diversity and then mined a software repository to measure how team productivity and turnover are impacted by gender and tenure diversity. Following the opposite order, Prana et al. [48] started mining software repositories to investigate differences in gender inclusion in projects across geographical regions, followed by a survey aimed at developers from the various regions about factors that can potentially contribute to differences in developer participation based on gender and geography worldwide.

MIXING involves choosing how to integrate or connect qualitative and quantitative data, which can be done during data collection, analysis, or interpretation. For example, in a two-phase project, mining software repositories can be followed by a gender inference approach to support the selection of women's data for a subsequent survey, connecting the two phases, as in [50]. In some cases, one form of data may support another, *embedding* a secondary form within a larger study. The researcher may weigh the collection of one type of data while using the other type to provide supplementary information.

Regarding metrics for inclusion, SE research has been advancing on measuring the sense of belonging [59, 60], which is the extent to which individuals feel like they belong or fit in a given environment [31]. Belongingness is a theoretical concept that is hard to observe directly, but it can be asked through different manifest variables (questions) and grouped on a latent construct. There are different instruments in the literature to measure a sense of belonging. The instrument used to measure belongingness in Open Source Software, for example, was based on the concept of a sense of virtual community [11] (a community that mainly interacts online) and included questions about feelings of membership as a member of the team, being known by others and knowing who to ask for help, feeling valued and perceiving the team is like home [60].

In addition to the methods considered, the actual implementation of these methods for research purposes can be improved. On the diversity lens, most of the literature related to minorities in SE and underrepresentation is still focused on gender [61], race [44, 51], neurodiversity [39, 42]. English confidence is a metric to evaluate inclusion for people who are non-native in English [53] and can include multiple questions to include both written and spoken communication and both technical and social contexts [60]. Socio-economic factors are also essential to be measured. For example, Goel et al. suggest that most research for end-user programming targets WEIRD (Western, Educated, Industrialized, Rich, and Democratic) users, while ignoring non-Weird populations that make up 85% of the world [29].

We need more diversity aspects and intersection of those, which is going to be discussed in the next section.

The overarching research goal for this theme is as follows:

Table 1: Methodologies and Metrics: Benefits, Harms, and Research Directions

Benefits (Utopia)	Harms (Dystopia)	Research directions
<ul style="list-style-type: none"> Enhanced inclusion metrics Comprehensive understanding of community dynamics Tailored intervention strategies for diversity 	<ul style="list-style-type: none"> The definition of inclusion not always clear Lack of comprehensive analysis tools Oversimplified interpretations of complex identities 	<ul style="list-style-type: none"> Bridging qualitative and quantitative research Developing new theoretical frameworks and theories from the data Utilizing online community data for inclusiveness measures

Research Goal: Develop methodologies and metrics to effectively analyze diversity and inclusion in software engineering, making use of mixed methods and online community data.

4.2 Intersectionality

The concept of intersectionality describes the ways in which social categories of identity, difference, and disadvantage, e.g., gender, race, ethnicity, sexual orientation, gender identity, disability, class, age, and other forms of discrimination, “intersect” simultaneously to create unique dynamics and effects [18]. Intersectionality suggests that different diversity aspects are not mutually exclusive and do not operate in isolation. Research also shows the negative consequences for individuals at the intersection of diversity categories in SE and computing. For example, Ross et al. show that fewer black women are introduced to CS than non-Black women and Black men [52]. In this case, Black women do not know whether their negative experiences should be attributed to their gender or race. Similarly, a recent study [62] shows that older women developers adopt various “survival strategies” to persist in the tech industry, and are uncertain whether their negative experiences in software development environments are due to ageism [8] or sexism.

Black women and veteran women are merely two possible intersections to consider when studying SDDI from an intersectional perspective. Many individuals also find themselves at the intersection of more than two diversity axes. Research suggests that White, able-bodied, and heterosexual male STEM professionals experience favorable treatment, while people with more intersections face reduced social inclusion, professional respect, career opportunities, salaries, and persistent intentions [17]. Therefore, more work is needed to understand the experiences of developers at the intersection of multiple diversity aspects.

Table 2 presents benefits, harms and research directions on intersectionality in SE. The benefits and harms clearly show the complexity of the theme and the dangers of ignoring intersectionality. Research directions involve improving measurements of bias, investigating the experiences of individuals with diverse identities not or under-explored in SE literature so far, considering the experiences of individuals across diversity axes, and designing interventions and guidelines to support developers who identify with multiple diversity aspects. The overarching research goal for this theme is as follows:

Table 2: Intersectionality and SE: Benefits, Harms, and Research Directions

Benefits (Utopia)	Harms (Dystopia)	Research Directions
<ul style="list-style-type: none"> In-depth understanding of diverse identities Enhanced methodologies for capturing intersectionality Empowerment through tailored interventions 	<ul style="list-style-type: none"> Potential for oversimplification in the analysis Danger of marginalization through one-size-fits-all policies and analysis Ethical concerns in data collection and analysis 	<ul style="list-style-type: none"> Developing a two-stage research approach to utilize both qualitative and quantitative data Understanding underexplored intersections of diversity in SE Designing interventions that respect and enhance self-perception and self-efficacy Adapting to AI-powered development and research environments

Table 3: Knowledge Transfer and SDDI: Benefits, Harms, and Research Directions

Benefits (Utopia)	Harms (Dystopia)	Research Directions
<ul style="list-style-type: none"> Seamless integration of research into industry practices Enhanced innovation through collaborative efforts Better alignment of academic curriculum with industry needs 	<ul style="list-style-type: none"> Fragmented and siloed knowledge pools Industry and educational practices disconnected from current research and vice versa in the area of SDDI Overlap in the actions, actions not visible to others 	<ul style="list-style-type: none"> Establishing frameworks for continuous exchange between academia and industry Cultivating partnerships for mutual knowledge enhancement Recognizing key actors from all areas of the quadruple helix

Research Goal: Understand challenges and motivate solutions to support developers who identify with multiple marginalized groups.

4.3 Knowledge Transfer

Substantial research activity is already ongoing in SE and beyond, targeting the effect of various diversity dimensions on the workforce. For example, existing work shows that masculine cultures can alienate women developers [25, 28]—yet, studies show increased inclusion of women in development teams can enhance productivity [63], community [16] and code quality [56]. However, the transfer of these findings to other actors is ultimately vital to enhancing software development and software quality. Table 3 summarizes the harms of ignoring knowledge transfer, benefits of successful knowledge transfer, and research directions for the coming years.

In the last decades, SE research has increasingly tried to show industrial relevance in published work. This is witnessed by an increasing amount of publications with joint academic and industrial authors, special forums for industry-relevant work, such as the SE in Practice track at the International Conference on Software Engineering (ICSE),⁶ a special issue in IEEE Software on sustaining

⁶<https://conf.researchr.org/track/icse-2025/icse-2025-software-engineering-in-practice>

software engineering knowledge transfer,⁷ or funding calls that require collaboration between academia and industry [6, 14]. This focus on industry-relevant research has led to substantial work on how to transfer technology and knowledge, typically from academia to industry (see, e.g., [30]). However, we explicitly question whether the transfer of SE research knowledge has indeed been successful.

Considering SDDI topics, we further believe that focusing solely on academia and industry for knowledge transfer is insufficient. SDDI initiatives are widespread beyond academia and industry—and fragmented. For example, government bodies pass legislation related to diversity and representation,⁸ and societal groups promote specific aspects of diversity⁹ and techniques toward a more inclusive society. Thus, knowledge transfer of SDDI research is essential for each of the different actors in the quadruple helix: society, academia, government, and industry [15]. As a result of this spread and fragmentation, encouraging actions and initiatives may overlap and may be invisible to other actors. Therefore, we argue that research that considers SDDI in SE needs to engage with all four areas in the quadruple helix.

Finally, re-considering the direction of knowledge transfer is important for research related to SDDI topics. In addition to transferring research results from academia to industry, society, and governments, researchers need to improve their knowledge of initiatives and the results obtained in the broader societal context. This also relates to the *Methodology and Metrics* theme, as methods that include stakeholders could be beneficial to reach this goal, e.g., participatory research or co-creation.

Overall, we summarize our discussion on this theme in the following research goal:

Research Goal: Engage in knowledge transfer among the quadruple helix of industry, academia, government, and society, considering both transfer to and from academia to the remaining actors.

4.4 Connections to Socioeconomic Understanding

Given the spread of IT across nearly all aspects of human life, we have to acknowledge that socioeconomic has an impact on our field. Diversity and inclusion are not merely SE problems. They are projections of much broader socioeconomic problems, which have been studied in research from multiple social science disciplines, to name a few, sociology, anthropology, education, etc. Compared to SE research, they have developed socioeconomic understandings of these issues at much larger scales [7]. Such large-scale understandings and small-scale context-focused research in SE could complement each other. By connecting with these societal scale understandings, we might better distinguish the unique problems in SE and common social problems, position ourselves and our research in the full social spectrum, understand diversity and inclusion problems' socioeconomic roots, inspire novel interventions,

⁷<https://www.computer.org/digital-library/magazines/so/call-for-papers-special-issue-on-sustaining-software-engineering-knowledge-transfer>

⁸For instance, the European Accessibility Act and the US Americans with Disabilities Act (ADA), Section 508

⁹For instance, ACM-W, which is "supporting, celebrating, and advocating for Women in Computing".

Table 4: Connecting Large Scale Socioeconomic Understandings: Benefits, Harms, and Research Directions

Benefits (Utopia)	Harms (Dystopia)	Research Directions
<ul style="list-style-type: none"> Better and more comprehensive understandings of diversity and inclusion issues within and beyond the software engineering industry Coordinated effort to address larger problems Potential impacts across traditional discipline boundaries 	<ul style="list-style-type: none"> Incorrectly attributing SE-specific problems to general socioeconomic problems Taking a passive attitude to wait for socioeconomic changes Ignoring the research results from other disciplines Using socioeconomic factors as an excuse for the inaction 	<ul style="list-style-type: none"> Exploring forms of connecting socioeconomic understandings with SE research in diversity and inclusion Developing customized interventions considering different groups' socioeconomic backgrounds Coordinating with social scientists to address national/international diversity and inclusion issues Preparing for the potential socioeconomic changes resulting from recent progresses in generative AI

and coordinate to tackle diversity and inclusion problems in SE as a part of global social forces. From a micro-perspective at the individual level, socioeconomic understandings could remind us to seek solutions for the workplace dystopia described in the S3.

Social scientists have established such societal scale understandings mostly by tracking the socioeconomic dynamics over relative long periods, represented by the major multi-wave, nationwide, or international surveys, such as the General Social Survey,¹⁰ World Value Survey,¹¹ and the Bureau of Labor Statistics,¹² to name a few. The results of these surveys could be integrated with our research through a number of different ways. The results could be used in quantitative analysis to identify potential relationships, e.g., the overall labor market dynamics and women's involvement in SE, in which data from the Bureau of Labor Statistics could be used. They might also provide contextual information in qualitative inquiries, e.g., the World Value Survey may help SE researchers interpret qualitative data about the differences in women's participation between the United States and China. Besides, when designing and delivering educational materials, these socioeconomic understandings can offer unique insights to help us better understand the audience.

Connecting SE to a large-scale socioeconomic understanding requires intensive interdisciplinary collaboration between SE researchers and social scientists. However, we seldom see SE research published in social science venues, and vice versa. In the 2030s, we expect there will be a significant increase in interactions between both sides. Although such connections may be beneficial, they are not without risk. In particular, it may lead to some inertia before certain socioeconomic conditions improve or to some excuses for inaction in our industry. Table 4 summarizes the potential benefits, harms, and research directions. We formulate the following research goal for this theme:

¹⁰<https://gss.norc.org/>

¹¹<https://www.worldvaluessurvey.org/>

¹²<https://www.bls.gov/cps/lfcharacteristics.htm>

Research Goal: Understand and address challenges inhibiting software engineers from disadvantaged socioeconomic backgrounds.

5 DISCUSSION

In the following, we discuss the four research themes jointly towards an agenda of SDDI in SE. We then add a brief discussion of how recent changes in AI and education relate to the outlined agenda.

5.1 An Agenda of SDDI

Our four research themes and their research goals jointly provide an actionable agenda, bridging gaps in SDDI to make the two utopian scenarios possible and avoid the two dystopian scenarios. First, appropriate research on *methodologies and metrics* must be developed to effectively analyze various aspects of SDDI in SE. Specifically, two concrete aspects of SDDI that we believe are of particular importance are the *intersectionality* of software engineers and the connection of *large-scale socioeconomic understandings* to SE practice. These two aspects need to be studied and understood more thoroughly to suggest appropriate SDDI initiatives and actionable principles for SE practitioners. Finally, SE research connected to SDDI will not impact education or practice without successful *knowledge transfer*. Given the relevance of societal and governmental initiatives to SDDI, transferring to and from these groups requires dedicated focus. In summary, our research goals for the four themes are as follows:

- **Methodologies and Metrics:** Develop methodologies and metrics to effectively analyze diversity and inclusion in software engineering, making use of mixed methods and online community data.
- **Intersectionality:** Understand challenges and motivate solutions to support developers who identify with multiple marginalized groups.
- **Knowledge Transfer:** Engage in knowledge transfer among the quadruple helix of industry, academia, government, and society, considering both transfer to and from academia to the remaining actors.
- **Connections to Socioeconomic Understanding:** Understand and address challenges inhibiting software engineers from disadvantaged socioeconomic backgrounds.

Research on SDDI typically deals with marginalized groups. As such, this type of research requires a constant focus on maximizing benefits while minimizing harms, especially to vulnerable groups. The contrast between utopia and dystopia in our scenarios highlights this fine balance in an extreme way. Metrics, diversity dimensions, and socioeconomic understanding can and have been used both to the benefit and to the disadvantage of various societal groups. As a research community, we must strike this balance in a responsible way.

5.2 The Impact of AI on SDDI

The recent progress in generative AI, exemplified by the advent of LLMs and the burgeoning trend of computing as a general education, holds transformative potential for SDDI research. These

advances are poised to revolutionize every facet of our agenda, sparking new avenues of exploration and understanding across research, industry, and educational contexts to build a more inclusive future in software development. We should be mindful that AI-based solutions not only inherit traditional SDDI challenges, but also come with new ones. For example, solutions produced by GitHub Copilot for Chinese prompts were found to be subpar compared to their English and Japanese counterparts [34]. This might create obstacles for developers preferring to express themselves in Chinese. Similarly, using ChatGPT-like solutions often involves tinkering, which is known to be a more common learning strategy among men than among women [10, 13]. In contrast, ChatGPT-like solutions could help several groups of developers who might feel more comfortable posing their questions to a machine rather than asking people, e.g., neurodivergent developers who commonly face difficulties in communication [42].

Regarding **methodologies and metrics**, AI may offer the unprecedented capability to bridge existing qualitative and quantitative methods, enabling the development of deep insights about SDDI from a large volume of data, such as online community data. For example, LLMs' automated sentiment and opinion mining features could significantly accelerate the process of analyzing qualitative data to identify SDDI-related content [37], and improve the effectiveness in quantifying hard-to-detect implicit biases [64, 65]. Their multilingual features may ease the process of research focusing on non-WEIRD populations. The survey design and execution process may also be partially automated with AI techniques; for example, LLMs could help summarize related literature, particularly literature outside the SE domain, to identify potential metrics for constructs related to diversity and inclusion. These methodologies and metrics can then be used to inform SE education and industry practices. Meanwhile, we must acknowledge that most AI technologies inherit biases and discrimination from diverse sources [26]. Thus, SDDI researchers must be cautious and vigilant when integrating AI into their methodological arsenal.

AI can also play a role in **intersectionality**, affecting SDDI in computing education and practice. In addition to the methodological benefits mentioned above, AI could play a positive role in SE education involving people with diverse identities. One of the major promises of AI is to provide personalized materials to people of different characteristics [21]. Thus, AI could bring individualized learning experiences to individuals of certain intersectionality, such as gender-sensitive, accessible software development learning materials for students (see S2: Education Utopia). Moreover, conversational agents powered by AI techniques have the potential to create psychologically safe development environments in which individuals of certain intersectionality would not feel embarrassed when interacting with AI. However, researchers must keep in mind that individuals from different identities might interact with AI technologies differently or that they might benefit differently from AI. For instance, studies report developers who identify as female and LGBTQ+ have significantly lower intent to learn and adopt AI-assisted coding platforms, while software engineers of racial minorities have a higher intent to upskill but also more negative perceptions of AI compared to their counterparts [47].

As mentioned above, the **knowledge transfer** of SDDI topics is essential for different actors in the quadruple helix (society,

academia, government, and industry). The key challenge is the invisibility among actors. AI technologies, due to their capability to automate knowledge discovery, may partially mitigate this challenge. LLMs could help automate the cumbersome process of identifying and distilling the widespread knowledge in the interdisciplinary literature and then compile it from fragmented pieces into organized knowledge bases or repositories [36]. Conversational agents powered by AI might facilitate the dissemination of information and knowledge among actors from different quadruple helix to increase the visibility of those actors' efforts. SDDI researchers may create domain-specific LLMs as the interfaces for engaging with key actors from other domains. Meanwhile, the relevant SDDI knowledge could be better integrated into their initiatives, including their effort to make computing education more accessible.

Generative AI technologies would inevitably change the **landscape of today's socioeconomic situations**. These technologies might create new disparities that have never been seen before. For example, well-paid professional labor markets such as software development might experience a reduction [2]. How can we make various minority group members suffer less if this happens? How can we reskill minority group members to participate in future work? How can we avoid further polarization of the labor market? To address these issues, SDDI researchers should collaborate with researchers from other disciplines to closely monitor the socioeconomic dynamics and develop forward-looking solutions. When it comes to educational contexts, AI could help to scale computing education to larger cohorts as the adoption of computing education rises across all disciplines [4]. In particular, AI can support learning for individuals who may not otherwise be able to receive such education due to their socioeconomic backgrounds—for example, learners from the Global South. However, access to advanced AI leads to a new digital divide [32]. While LLMs are almost ubiquitous in high-income economies, reliable Internet access remains a big issue in many low-income economies [35], contributing to the Workplace Dystopia (Scenario S3) described in Section 3. In this process, people from minority groups may lose their human anchors, which gives them a sense of belonging that keeps them in the area (see Scenario S4: Education Dystopia). Hence, SDDI research should not underestimate the potential socioeconomic changes caused by fast-evolving generative AI technologies.

6 CONCLUSIONS

Software affects almost all areas of modern life, affecting user behavior, well-being, and decision-making. Software engineers design and develop software applications—yet the diversity of software development teams does not represent the diversity of the global population. To this end, this work presents insights from SE researchers and practitioners on challenges and research opportunities to promote software developer diversity and inclusion (SDDI). We provide motivating utopian and dystopian scenarios describing the effects of diversity on SE practice and education in 2030 and discuss ways to promote SDDI through research methodologies, intersectionality, knowledge transfer, and socioeconomic understanding to navigate the changing landscape of software development. We further briefly discuss the potential impact of the recent progress in generative AI and the burgeoning trend of computing as a general education.

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