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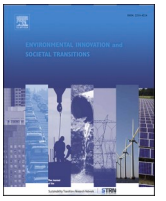
2023-03
Elsevier B.V.
http://hdl.handle.net/10138/355747
Moilanen, F & Alasoini, T 2023, 'Workers as actors at the micro-level of sustainability transitions : A systematic literature review', Environmental Innovation and Societal Transitions, vol. 46. https://doi.org/10.1016/j.eist.2022.100685

Environmental Innovation and Societal Transitions 46 (2023) 100685

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist



Workers as actors at the micro-level of sustainability transitions: A systematic literature review

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ARTICLE INFO

Keywords:
Sustainability transition
Work
Practice
Actor
Organisation
Employee

ABSTRACT

Work and workers have been neglected topics in sustainability transitions research. Our systematic literature review of 28 academic papers on the subject reveals five ways in which workers are affected or otherwise linked to transitions, indicating the relevance of further empirical studies on the role played by different groups of workers. First, environmental policies and other macro-level changes have indirect consequences for workers. Second, new sustainable work practices emerge or face insurmountable obstacles depending on meso- and micro-level change dynamics. Third, workers may adopt mediating positions and act as intermediaries in transitions. Fourth, novel educational programmes evolve to equip workers with new skills, and fifth, transitions may lead to the creation of new jobs in the labour market. Co-evolutionary change dynamics of sustainability transitions affect workers in both formal and informal forms of employment, and these questions in accelerating transitions require further attention.

1. Introduction

Sustainability transitions (STs) are major changes in socio-technical systems based on co-evolution and multi-actor interactions between social groups on a path toward sustainable production and consumption patterns. Socio-technical systems provide strong structuration, path dependencies, and lock-ins due to a high level of institutionalisation of their elements, such as technologies, policies, markets and values, which act as constraints to any sudden or radical change in such systems (Fuenfschilling and Truffer, 2016; Geels, 2004, 2011). In the early ST literature, the transition of a socio-technical systems was considered to take place through the emergence of niche innovations, i.e. alternative technologies and practices that require protection (Smith and Raven, 2012). The understanding of potential transition paths has since diversified to include a variety of change trajectories (Geels and Schot, 2007), and today, a number of perspectives to understand STs has emerged (Köhler et al., 2019). The early emphasis on technology-centred analysis in the field has received criticism, and multiple scholars have urged for paying more attention to the role of actors and micro-level changes in transitions (Farla et al., 2012; Fischer and Newig, 2016; Upham et al., 2021; Wittmayer et al., 2017).

Scholars refer to STs as multi-actor processes where actors take different positions and roles (Avelino and Wittmayer, 2016; Smith et al., 2005). There are actors with the power to influence the direction of change, and there are rule followers with a more limited ability to affect the course of events (Avelino and Wittmayer, 2016; Geels, 2004). However, Fischer and Newig (2016) argue that actors are often only implicitly included in the analyses, and their positions and social relations insufficiently investigated, although STs often

This research was financed by Finnish Institute of Occupational Health.
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https://doi.org/10.1016/j.eist.2022.100685
Received 18 February 2022; Received in revised form 18 November 2022; Accepted 28 November 2022
Available online 7 December 2022

affect actors and their habitual roles in society (Wittmayer et al., 2017). Upham et al. (2020) call for extending analysis of the 'social' aspect of socio-technical transitions. The authors, together with Bögel et al. (2019) and Köhler et al. (2019), assert that directing more research toward micro-level transition processes in organisations and the individuals within would be welcomed for ST studies to better understand change. ST research currently lacks the tools needed to analyse actors' activities in implementing changes at the meso- and micro-levels (Hölsgens, 2021), although there are approaches presented to fill these gaps, such as practice theories (Hargreaves et al., 2013; Shove and Walker, 2010) and the concept of transition arena (Jørgensen, 2012).

Some of the criticism presented above can be answered by taking a closer look at workers as actors who are embedded in product and service production processes. Work is a fundamental topic in the social sciences, but workers' role is barely addressed in the ST literature, with the exception of their role in producing technology (Geels, 2004, p. 900), or single articles discussing macro-level changes in occupational structures (Bernardo and D'Alessandro, 2016; Prinz and Pegels, 2018). In the previous literature that links work and sustainability, climate change has often been portrayed as a global megatrend that transforms the world of work. However, as Schulte et al. (2020) note, neither academic papers nor grey literature on the 'future of work' have paid much attention to this association. The lack of research between work and sustainability has also been recognised by other scholars (Bottazzi, 2019; Hoffmann and Paulsen, 2020; Iskander and Lowe, 2020). Considering the criticism of previous studies on STs and the relatively small number of studies on work and sustainability, novel conceptualisations on the topic are needed.

Even though the role of workers as actors in STs remains largely unexplored, we assert that Geels' (2014, p. 262) conceptualisation of industries undergoing socio-technical change offers a valid theoretical standpoint for such an attempt. According to Geels (2014), firms are constrained by the strong structuration of the industry regime, where regime refers to the intangible elements of the socio-technical systems, such as rules, regulations, and norms. This structuration contributes to the maintenance of the regime, making deviation difficult or even impossible for in-industry actors. In addition to management, workers in these organisations are embedded in the industry regime and face the pressure to follow the rules, norms, and commonly shared understandings adopted in the regime. This observation is not new; the early science and technology studies from which ST research originates stress how engineers' routine-like work practices and related skills play an essential role in organisations' path-dependant change and innovation development (Bijker et al., 2012; Dosi and Nelson, 1994; Rip and Kemp, 1998). The industrial rules enable and constrain the activities of workers, contributing to the continuity of current production models and a high level of structuration of socio-technical systems (Geels and Schot, 2007).

However, industry regimes (like any other social institutions or organisations) are not immune to change. Change in an industry regime is a co-evolutionary process between the firms in the industry and other actors in their external environment, such as customers, suppliers, policymakers and social movements (Geels, 2014, p. 266). In-industry organisations may also implement change processes that aim to strengthen their sustainability (Dunphy et al., 2014; Gouldson and Sullivan, 2013; Kuramochi et al., 2020). These processes include innovations, strategies, practices and cultural meanings (Jennings and Zandbergen, 1995), which challenge path-dependant rules and practices within the industry regime. These organisational changes can be viewed as niche innovations that aim to disrupt or transform the regime and its locked-in mechanisms (Smith and Raven, 2012).

Change processes that nurture a shift toward more sustainable production pattern do not have to emerge only in a top-down manner from management to shop floor practitioners; workers can also play a role in organisational change processes and initiate new norms and ways of doings. Süßbauer et al. (2019) argue that employees can influence organisations' sustainability in at least three different ways: (1), by transforming their everyday experiences into sustainability initiatives; (2) by networking with customers and other stakeholders with an eye to contributing to change; and (3) by reshaping their daily work practices due to their organisations' internal sustainability actions. In all these cases, workers play a role in realizing a shift to sustainability through changes that take place in daily work. This bottom-up perspective has also been noted by other scholars by showing how workers can reconfigure their vocational practices (Hoolohan et al., 2021) or receive education and training from the employer to initiate change (Davis and Boulet, 2016). Thus, by investigating shop floor activity and the largely neglected role of workers as a stakeholder group in organisations' efforts to seek sustainability (Wolf, 2013), we can substantially improve understanding of the social dimensions of STs.

This article aims to highlight the role that workers can play as actors in STs in the hope of inspiring future research on the topic by the ST academic community. Our premise is that due to the holistic and multi-actor nature of STs, the role of work organisations and workers, in both formal and informal work, should be better understood in the analyses of STs. We assert that industry regimes in STs include various change dynamics where work organisations and workers are affected. These changes set in motion processes toward more sustainable means of production where work organisations and workers may seek to create niche innovations that redefine their habitual practices, rules and cultures.

The research questions are as follows:

1 How does the previous empirical sustainability transitions research connect with workers at the micro level?
2 What kinds of co-evolutionary change dynamics can be identified between sustainability transitions and workers?

We sought to answer these questions by conducting a systematic review at the intersection of work and STs. This article contributes to earlier ST literature in three ways. First, it provides a novel categorisation on the relations between STs and workers, based on content analysis of the reviewed articles. With the help of the analysis, we aim to show that it is not only the management, senior professionals, or any other group of experts who are involved in sustainability-orientated socio-technical change, but also many other types of workers in multiple industries may be engaged in STs, as also maintained by Süßbauer et al. (2019). Second, we propose a novel conceptualization, inspired by previous works of Geels (2014) and Bögel et al. (2019), to connect our findings with previous research, hoping that this may guide future attempts in investigating workers and STs. A better understanding of workers' involvement

is crucial in filling the gap between the low-carbon vision and its practical implementation across economic sectors. This will also advance our understanding of micro-level transitions and pave the way for future research on work and STs. And third, the article raises new questions and areas of investigation for both transition studies and work research.

Not all work is done as part of the formal economy. The International Labour Organisation (ILO) (2018) estimates that more than 60% of the world's employed population is involved in the informal economy, mostly in developing countries. Due to the prevalence of informal work in large parts of the world, we prefer to use the term 'worker' instead of 'employee' in the empirical part of our paper.

The remainder of the article is organised as follows. Section 2 explains how we gathered the data and what criteria we used for the inclusion and exclusion of the reviewed articles. The results of the research review are presented in Section 3. The results are discussed in Section 4, including a more theoretical enquiry of the results, and Section 5 contains the conclusion.

2. Data and method

According to Petticrew and Roberts (2006), the relevance of systematic reviews lies in their potential to scrutinise large bodies of literature and to transform them in new and informed ways. This review examines how workers have been investigated in peer-reviewed research on STs. Work and workers as actors in transitions are underexplored in transition studies, as shown above, although several papers have contemplated the issue in recent years (e.g. Süßbauer et al., 2019).

We searched for articles for this review in February 2021 from the Web of Science (WOS) database, and we repeated the search in the Scopus database in March 2021. Because the initial target of the search strategy was to find articles that discussed work-related questions in the context of STs, we set the search words accordingly to refer both to work and transitions. Both authors talked about the search terms. The work-related search words were 'job*', 'work*', 'employ*', 'labour', 'labor', 'occupation*', 'practitioner*' and 'profession*'. The transition-related search words were 'sustainability transition*', 'socio-technical transition*', 'societal transition*' and 'low carbon transition*'. The full search word string is presented in the Appendix. The timespan of database searches was not limited. The chosen search word combination produced 552 results from WOS and 660 from Scopus. After deleting duplicates, the final number of sample articles was 838. The flow chart of article selection is presented in Fig. 1.

Both authors were involved in selecting the review articles to increase the validity of the study. All the topics and abstracts of the 838 articles were read by the first author, and the second author read the abstract and topic of every fifth article. In the first coding cycle the inclusion of the articles was assessed simply by whether the article (based on the abstract and topic) discussed human work in the context of transitions. The articles were categorised under 'yes', 'no' or 'uncertain'. Reasons for why the categorisation was uncertain were written down.

Most of the 838 articles contained work-related search terms such as 'work' or 'employ' as a verb, where the authors in question described the course of the research process. For these reasons, most of the articles were irrelevant to the research questions. At this stage, we also excluded articles that addressed the work of researcher, volunteer work or which dealt with purely methodological

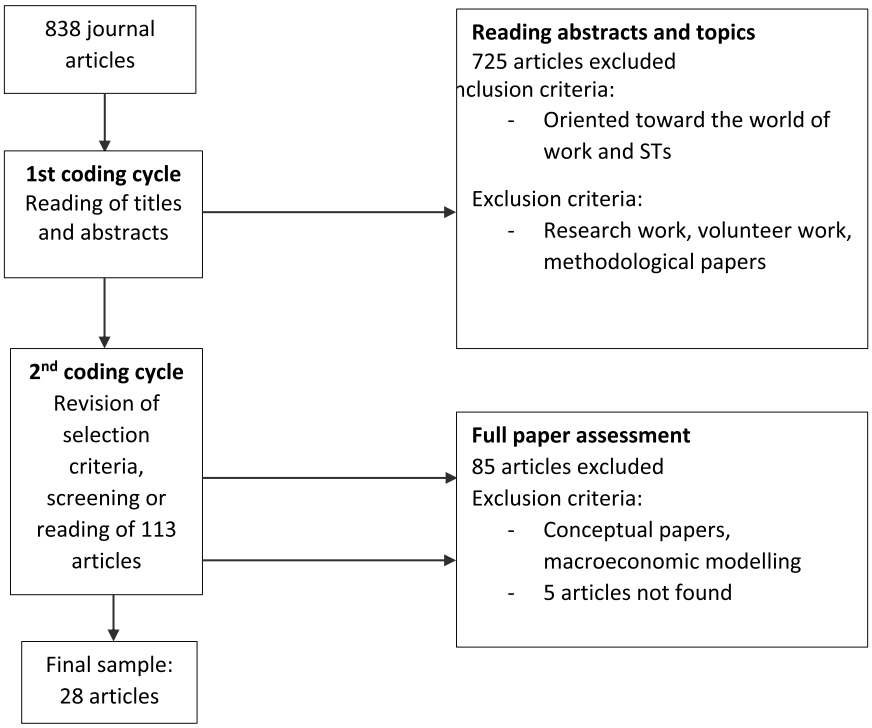

Fig. 1. Flow chart of the article selection process.

issues. After sifting through all 838 abstracts, the authors talked about their categorisations, in particular the 'uncertain' category or cases where the coding was contradictory between the authors. The final number of articles on human work-related questions in the context of transitions was 113.

The remaining 113 articles discussed work in large diversity. Because of their heterogeneity and the initial aim to grasp the impacts of STs at the micro level at work, we adjusted and narrowed the inclusion criteria. We refined the focus on empirical research on STs and everyday work, where workers or groups of workers at the grassroots level are the key topic and unit of analysis in the empirical investigation. We included only full-length and peer-reviewed papers, book chapters and conference papers in the sample. We set extensive coding categories before the second stage of article selection; these categories included a short summary of the content, research method, country, economic sector, and an idea of whether the article addressed individuals or a group of people. After revising the inclusion criteria, we read all abstracts and topics for the second time, and we coded articles wherever data were available. We excluded some articles (such as purely conceptual papers) based on abstracts, but we read most papers in full length for decision-making.

Since the topic of the review is new for ST studies, we followed a different procedure in coding than Markard et al. (2012) and Raven et al. (2021), who only included articles that referred to 'core publications' of ST research in their review. Markard et al. (2012) defined these articles as texts that have impacted the development of STs as a research field. By following a similar procedure, we could have excluded some relevant studies on the topic since we did not want to limit the sample to specific interpretations or frameworks of STs. However, in the coding phase, we coded the articles to determine whether they made a reference to the core articles. A complete list of the inclusion and exclusion criteria of the articles is presented in Table 1. The final number of reviewed articles was 28, as seen in the Appendix.

We examined the final sample with a data-driven content analysis. Since not much research has been conducted on work and STs, we did not regard using any ready-made theoretical framework as meaningful in the analysis, and we scrutinised the content inductively. The taxonomy presented in Section 3 is based on categorization of papers discussing similar topics into same groups. Consequently, the chosen categorisation is founded entirely on the analysis of the first author.

The research method has some limitations. For instance, we only reviewed articles published in English. In addition, because of the chosen search word strategy, our sample of articles did not include those that had referred to the name of an individual occupation (such as 'electrician' or 'teacher'), sectoral search terms (such as 'energy transition' or 'food transition') or terms such as 'organisation change' or 'sustainability innovation'. The use of these words in the database search could have brought up relevant articles on workers and micro-level transitions. However, since we aimed to focus in particular on previous research discussing workers and transitions (and not specific occupations), we chose the search words with this target in mind. Moreover, including search words referring to organisational change for instance, would have increased the number of sample articles significantly, making in-depth qualitative analysis difficult. Given these choices, we may have excluded some relevant articles that had corresponded with our research questions. We also acknowledge that the use of different concepts and theoretical frameworks would provide a more nuanced perspective for the study on the complex connections between workers and transitions. However, we believe that our final sample of 28 reviewed articles is sufficient for our purpose of revealing the micro-level connections and change dynamics between STs and workers which helps fill existing research gaps. At the same time, we point out that the categorisation we present in Section 3 is not exhaustive, and far-reaching generalisations based on the results are not possible.

3. Results

The 28 sample articles were published between 2012 and 2021. In recent years, the number of publications linking STs and workers has increased (in line with an overall growth in ST studies). In 2012, there was only one article published on this topic, but in 2020 and 2021, there were already five published articles per year. Most of the reviewed articles used qualitative methods for data collection, and case studies were the most popular method mentioned. Only two of the articles used a quantitative survey for data collection.

Thematically, the articles discussed the work of multiple economic sectors. The roots of ST research focusing on greenhouse gas-intensive sectors are seen in the sample, as most articles addressed the work of the agri-food sector (6 articles), the housing and construction sectors (4 articles), and the energy sector (3 articles).[1] However, the results indicate that STs also touch upon workers in many other sectors, such as health care, water, design and education. Four of the articles referred to the work of multiple occupational groups. Most often, the articles mentioned occupational groups that include highly educated professionals such as architects, civil servants and teachers, while only three articles focused on manual labourers, such as recycling and mining workers. Geographically, most research was conducted in Europe, although articles also included cases from Latin America, the Middle East, Asia and Africa. More detailed information on the reviewed articles and coding categories is available in the Appendix.

As noted, we analysed the 28 articles with a data-driven approach to investigate the connections between STs and workers at the micro level. As a result of the content analysis, we formed five categories of topics from the sample data, which are presented in Table 2. These categories illustrate a wide spectrum of effects that STs may have on workers. The first category, 'indirect impacts on workers', consists of illustrative cases on how a change in workers' external environment has an indirect spill-over effect on them. The second category, 'novel work practices', involves how work practices need to be changed to make a shift toward sustainable production and to decrease the environmental impacts of work. The findings also suggest that work practices may be locked into unsustainable

[1] It is important to note that the search strategy did not include words that illustrate sectoral transition (such as 'energy transition') and this may explain why the number of articles discussing work on the energy sector is small.

Table 1
Inclusion and exclusion criteria of the second coding cycle of 113 articles.

Inclusion criteria	Exclusion criteria
Articles with empirical data	Research work, role of researchers
Everyday work life	Macroeconomic modelling
Articles discussing an occupational group	Volunteer work, unemployed people
Skills and knowledge at work	Social sustainability
Ecological or environmental sustainability	Methodological papers
Both qualitative and quantitative approaches	Research reviews
Full-length research articles	Conceptual or theoretical papers
Book chapters	Labour unions
	Commuting, work mobility
	Policymakers
	CEOs, entrepreneurs

Table 2
Description of the categories.

Category name	Description	Number of articles
Indirect impacts on workers	Workers are affected at the micro level by changes occurring at the macro level	3 articles
Novel work practices	Old-established and unsustainable work practices are questioned, and workers face the pressure to adopt new ways of working	13 articles
Professional sustainability mediators	Workers mediate sustainability through their work role, or a sectoral organisation mediates sustainability for employees in a sector	6 articles
Niche skills and education	Sustainability transitions manifest as work-based learning and institutionalised educational programmes for workers	4 articles
Niche jobs	Sustainability transitions create new job opportunities for workers	3 articles

modes and that altering them is not necessarily easy. The third category, 'professional sustainability mediators', indicates how workers may have mediating functions that speed up STs. Mediation may be pushed forward by an occupational group that is capable of advancing sustainability in the daily tasks of its members, or by an organisation that shares knowledge on sustainability-related issues for an occupational group. The fourth category, 'niche skills and education', entails how sustainability issues diffuse into novel education for workers to renew their skills that contribute to transitioned production. The last category, 'niche jobs', refers to new jobs that have emerged due to a transition.

Before discussing our findings in more depth, we would like to underline that some articles could have been categorised into more than one group since they include different work-related elements. Emirbayer and Mische (1998) and Raven et al. (2021) also observed the challenge in formulating exclusive categories in qualitative data analysis. Following their example, we based our categorisation of the articles on the dominant perspective implied in the paper. Moreover, the findings are discussed in one category only, with the exception of one article that contained four different empirical cases. Results and the interconnections between the different categories are addressed in more depth in Section 4. Next, we move on to our categories in greater detail.

3.1. Indirect impacts on workers

Three of the articles explored how work changes due to an external factor, such as policy or market changes. These factors are not directly linked to work, but they indirectly affect workers due to their interconnections with key element of the industry regime. This relationship between work and STs characterises the just transition point of view, showing how issues beyond workers' immediate sphere of influence constrain their opportunities for work and affect the course of a transition.

Changes in public policy may have far-reaching consequences for workers. Guibrunet (2021) shows how regulative efforts to improve Mexico City's waste management led to the deterioration of local working conditions, or even to the complete loss of jobs for local workers. Guibrunet asserts that this was caused by the municipal administration's insufficient understanding of the informal workers' role in maintaining the city's waste management. Fischer-Kowalski et al. (2020) also present a 'jobs versus environment' complex where habitual ways of working have seriously degraded nature. The authors investigated in tandem how the local environment was regenerated through conservation policies, and how local jobs could be transformed or partially replaced by new ones (Fischer-Kowalski et al., 2020).

In addition to Guibrunet (2021) and Sovacool et al. (2021) investigated the justice of transitions through four different case studies, focusing on the vulnerabilities that an energy transition may reveal. Workers in the German solar panel industry and French wine growers experienced setbacks and a loss of work due to market changes and inefficient environmental legislation. The cases aptly illustrate how national climate targets, such as nature conservation or the abandonment of fossil fuels, can have broad impacts on workers.

3.2. Novel work practices

Most articles described individual work practices and processes and their connections to the environment. The role of practices and their change in contributing to STs has been noted by multiple scholars (Laakso et al., 2021), and practices have also been investigated in the workplace (Paillé, 2020; Süßbauer and Schäfer, 2018). Articles on changes in work practices approach the topic from various angles ranging from cognitive decision-making processes and the use of technology at work to the holistic shift of everyday work tasks, coined 'occupational reconfiguration' by Hoolohan et al. (2021). Two articles (Meek, 2016; Wylie, 2020) demonstrate how work practices can be resistant to change despite their negative environmental impacts or perceived external pressure to change.

Some of the articles in this category indicate how workers can deliberately shape their work practices and reduce the environmental impacts of work. Increasing awareness of climate change and the perceived environmental impacts on one's own work practices is a premise for reconfiguring daily work activities to diminish environmental impacts. Dobson (2019) views colleagues and epistemic networks as a potential arena for individuals' on-the-job learning on sustainability. The dialogue on climate change and its links to work can initiate a cognitive process that leads to changes in work practices. This peer-to-peer collective learning may also result in an informal expansion of sustainable work practices in other work-related professional networks.

However, workers' environmental awareness and motivation to prioritise sustainability are not realised in their daily work in a straightforward manner. Many of the reviewed articles illustrate how work practices are shared with others when work is done in collaboration with workers from different fields or organisations (De Koning et al., 2018; Gaziulusoy and Ryan, 2017; Hemström et al., 2017a, 2017b). For instance, a shift to novel construction practices does not take place in the work of architects unless their collaborators (such as engineers, contractors and suppliers) are willing to engage in re-shaping habitual practices of construction (Hemström et al., 2017b). The motivation of a single individual or occupational group to engage in sustainable work practices does not easily arise if co-workers involved in multi-actor work processes do not adopt sustainability-orientated practices simultaneously.

New technologies are often the focus of ST research, but only one article primarily dealt with work life changes due to technological change. Wihlborg et al. (2019) discuss the challenge of diffusing the use of novel water management technologies and practices in Swedish municipalities. In their analysis, the authors expressed, amongst the seven identified barriers, how employees' lack of knowledge on sustainable technology and its maintenance, as well as a lack of networks and insufficient education, can hinder the rooting of innovation. The use of new technology at work was also discussed in the context of farming as a change in work amongst other factors, such as learning processes to use technology (Manuel-Navarrete and Gallopín, 2012).

Case studies on work practices in the agricultural sector indicate how changes in work practices can eventually lead to holistic transitions. Manuel-Navarrete and Gallopín (2012) and Vankeerberghen and Stassart (2016) examine how farmers shifted from traditional farming methods to novel cultivation tools, including 'deep changes in the organisation of production' (Manuel-Navarrete and Gallopín, 2012, p. 329), and Davidson et al., (2016) explore how the emergence of mad cow disease made some farmers shift to organic farming. These cases imply how, in agriculture, a holistic transition from an old professional practice to a new and more environmentally sustainable one can be realised. However, at the same time, the authors stress the significance of a favourable setting as a contributing factor to transitions, such as extensive services and public–private collaborations that were available for the farmers (Manuel-Navarrete and Gallopín, 2012).

Employees' green behaviour (also called 'environmental citizenship behaviour') is a relatively well-established approach in investigating sustainability at work with a focus on employees' action (Francoeur et al., 2021; Norton et al., 2015). However, only two articles discussed environmentally friendly work behaviours in the context of STs. Mi et al. (2019) investigated the connections between employees' environmental citizenship behaviour and employers' leadership methods. Parkhill et al. (2015, p. 67) looked at how hospital employees turned down introduced pro-environmental behaviours, which they did not consider to be the 'core part of a workplace practice'. The authors emphasise that climate policies impact many types of communities, many of which may lack tools to implement policies in practice. Their article is also the only one where the unit of analysis was the workplace; other articles focused on individual workers, networks of workers or professional groups.

Two of the articles referred to the work practices of occupational groups, namely chefs and farmers, and their stability by showing how practices are not necessarily changing despite their clear connections to unsustainable production. Wylie (2020) shows how chefs did not pay much attention to assessing the connections between their cooking practices and climate impacts. Even though turning food production sustainability all the way from the field to the table is a well-known public policy issue, it was not translated into daily practices amongst chefs. Maintaining culture and tradition may also be an important reason for sticking to old ways, as revealed in another study on agricultural work (Meek, 2016). This study demonstrates that although knowledge and skills on sustainable farming practices are available, they are not necessarily taken in to use due to workers' respect for traditions.

3.3. Professional sustainability mediators

Six of the articles refer to how workers in a given field mediate sustainability in their daily actions. The intermediation mentioned in the articles evokes regime-based transition intermediation, where regime actors adopt intermediary roles (Kivimaa et al., 2019). One obvious example of such role is the work of consultants. Sørensen et al. (2018) show how consultants' work includes four forms of 'transition work', including mediation, and how their professional agency enables them to influence socio-technical change through their work roles. Consultants' work has always included calculations, the sharing of information and persuasion work; it is only now that their practices have increasingly become attached to a sustainability agenda. In the case of Belgian biogas, regime change led to collaboration between gas operators and biogas producers, actors with no previous mutual relationship (Smink et al., 2015). Here, a consultant, as the intermediary, had the crucial role of mediating collaboration amongst worker groups representing the two

professional communities.

In the housing sector, professionals have also turned into mediators (Cauvain and Karvonen, 2018; Peltomaa et al., 2020). Housing managers play a central role in sharing information on energy efficiency and other energy issues in the housing units they manage. The professionals can, through their work role, significantly advance the sustainability of the apartment units under their management (Peltomaa et al., 2020). However, as Sørensen et al. (2018) note there is variation in consultants' sustainability agency depending on contextual factors, such as customers' concerns, autonomy and personal interests, a fact also observed by Peltomaa et al. (2020). In the agricultural-food sector, also retailers play a key role in sharing knowledge about novel products and easing the market entrance of sustainable food through their intermediary position (Forssell and Lankoski, 2018).

One of the cases mentioned an intermediary organisation that emerged to share information on sustainability for a specific occupational group. A case from Poland involved how agricultural sector intermediary organisations share knowledge and education and provide networks for farmers interested in organic farming (Skrzypczyński et al., 2021). This case illustrates a typical niche intermediary (Kivimaa et al., 2019) that supports a group of professionals in a single economic sector in adopting novel practices and scaling up sustainable innovations.

3.4. Niche skills and education

Four of the articles examined how a shift to sustainable production creates demand for novel skills in the labour market and what role the education of workers may play in this process. Rosenberg et al. (2018) discuss how sustainable development and green skills can be advanced in both university education and on-the-job learning. In their assessment, green skills included various technical, transformational and relational skills, such as integrative thinking and project management. However, the authors noted how green policy documents seldom refer to skills needed for the green economy, either in the context of the workplace or an educational institute. This indicates that the question of how skills will be trained for workers is probably not given enough attention. Educational institutes are also mentioned by Lambrechts et al. (2017), who examined how sustainability initiatives from university networks and professional development plans were integrated into graduate programmes and teachers' work at institutions of higher education in Belgium. However, the top-down managed implementation was not successful, and some employees viewed sustainability as a threat to their professional autonomy. The authors maintain that sustainability may be better integrated into education when workers feel empowered and the whole organisation seeks to become sustainable simultaneously in its other areas of operation (Lambrechts et al., 2017).

The role of education in STs was also discussed from the point of view of an occupational group. Water resource management and water scarcity are central environmental issues in North Africa and the Middle East, but water management has become even more complex due to its dependencies on the essential food and energy systems. In their assessment, Dehnavi and Al-Saidi (2020) stress the importance of boundary crossing between work and education, as well as the provision of real-life examples during education, for new skills obtained to become rooted at work.

Metelerkamp et al. (2020) explore South African knowledge networks of organic farming. The authors asserted that even though there is a high demand for organic farming skills, knowledge diffusion and learning are challenged by the fact that knowledge on the topic is dispersed amongst multiple professionals and formal educational institutes do not have the capacity to arrange education programmes. Since the number of young citizens entering work life is high, the authors argue for the need for flexible knowledge networks to support learning in organic niches. Educational institutes are not seen as able to do this, and the majority of young people do not end up in formal institutions at all (Metelerkamp et al., 2020).

Even in situations where novel educational programmes and courses are available, professional knowledge on sustainability does not necessarily become used as workers may confront barriers in the workplace. Dehnavi and Al-Saidi (2020) call fresh graduates 'change agents' who may face long-established attitudes and scepticism when entering work life. *Re*-skilled employees themselves might not solve existing challenges, but old employees in the organisation may need new skills as well. Thus, STs call for educating young workers with sustainable skills and re-skilling workers already involved in the labour market.

3.5. Niche jobs

Three articles discussed how seeking sustainability can generate new jobs in the labour market. Svennevik (2021) examines how changes in the transportation sector influence individual automobility by increasing the use of car-sharing services. The service suppliers include both old and new actors as well as commercial and non-profit organisations, most of which operate with platform logic. In addition to the fact that platform-based businesses create new platform jobs, they also alter the accustomed roles in the market by turning ordinary citizens into service providers next to companies.

However, not all jobs that emerge due to transitions are 'decent' despite expectations and visions set for transitions. Alonso-Fradejas (2021) examines how the growing demand for bio-based raw materials created new jobs around cultivation of biomass in Guatemala, and Sovacool et al. (2021) show how e-waste recycling and mining work have expanded due to escalating energy transitions. The jobs discussed pose risks to workers' health and safety, but given the lack of good alternatives, they provide the workers' the only means of earning a living. In this way, decent jobs expected from the societal shift toward carbon neutrality do not necessarily come into being, especially in locations with no decent labour legislation.

4. Discussion

Our research interest stems from the observation that prior studies on STs have largely neglected the potentially crucial role played by workers. With the help of this literature review, we have shed light on the everyday embeddedness of workers in production processes located in various organisations and industry regimes. We consider this relevant not only for achieving a better understanding of micro-level transition processes and the significance of the actors within, but also for realizing just transition to sustainable production and low-carbon society. Here, we first discuss our empirical findings and their implications. In the latter part of this section, we examine the findings in an industry regime framework inspired by previous research work by Geels (2014) and Bögel et al. (2019) with an attempt to integrate the results with previous ST research.

To answer our first research question on how STs connect with employees at the micro level, we categorized our findings into five groups, which are presented in Table 2. Even though workers and their daily actions have been overlooked in previous research, the findings show that STs may connect with workers in many ways. As presented in the table, STs may embody in novel work practices, or emerge as a demand for formal education to provide new skills for workers, or via other kinds of indirect effects of transitions upon workers. A common element present amongst all the groups is that STs usually appear to workers as requirements for changes at their work; Old ways of work can become obstacles to STs, but with new skills they can be crossed. Understanding the dynamism and stability characteristic to STs could be advanced by paying attention to work in future studies in the field.

Previous research on actors in transitions has focused on the sectoral level, such as the government and company actors (Fischer and Newig, 2016) or individuals who act as consumers, citizens, or technology users, as noted by Upham et al. (2021). We bring out that transitions also affect workers and worker groups of many kinds, and due to this entanglement with STs, workers should also be seen as actors in transitions. However, most of the reviewed papers did not explicitly treat workers as actors, but in most cases as mere informants for the purpose of gathering data on socio-technical change (Wihlborg et al., 2019), or simply referred to workers' lack involvement as a barrier to STs (Dehnavi and Al-Saidi, 2020). Addressing the focus of empirical studies to also cover workers in transitions in a more systematic manner has the potential to diversify the view of their role as potential actors in advancing STs at their own work or, alternatively as objects in interventions leading to transitions and of their indirect consequences.

Directing the empirical focus toward workers can also bring new insight to technology-centric ST studies (Farla et al., 2012; Upham et al., 2021). Our findings highlight the social aspects of STs, as only a few of the reviewed articles investigated the use and adoption of technology at work. Instead, the findings emphasize the centrality of workers' skills, occupational cultures, or existing ways of working, which can in some cases be important boosters of or constraints to the adoption of niche innovations. Research should

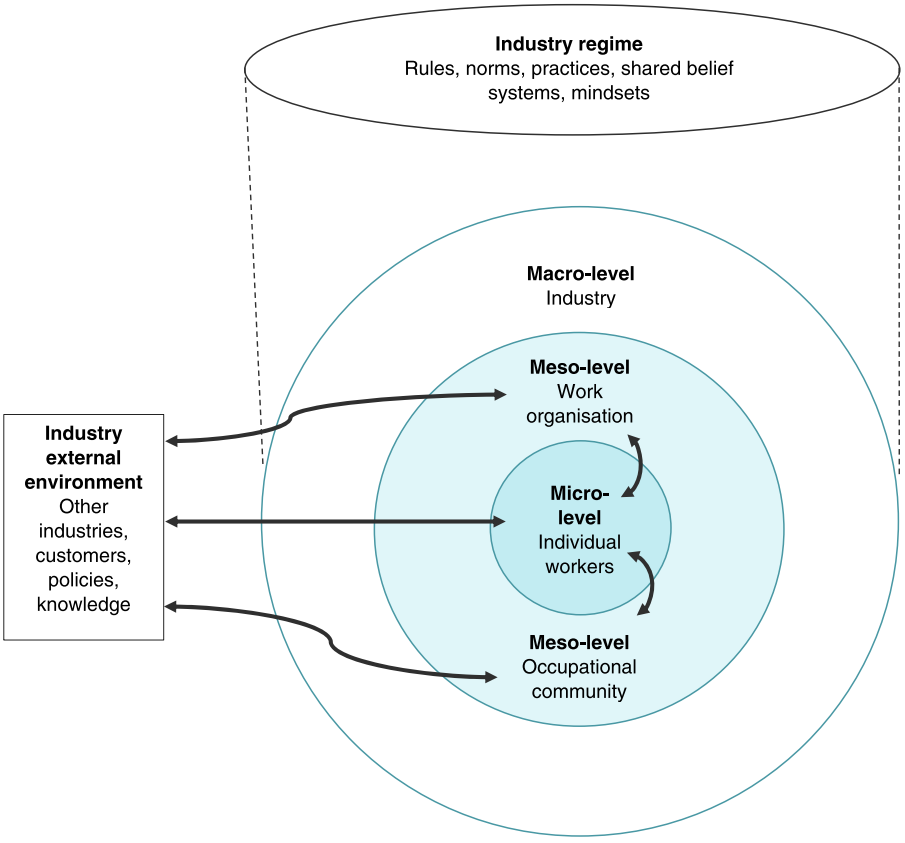

Fig. 2. Change dynamics at an industry that affect workers in the micro-level.

increasingly include issues that relate to the social nature of change, such as actors' ability to adopt innovations, as observed by Hölsgens (2021) and shifts in their roles (Wittmayer et al., 2017). Our findings indicate that workers can play an important role in the implementation of sustainable production processes in their respective economic sectors, which do not relate only to their own jobs, but also to activities in their work organisations or other occupational communities. However, as our findings also show, workers do not always play a role. Workers often lack the skills and the needed education or practical means to contribute to the implementation of changes in their work environment, considering, for example, their own work organisations' and communities' reluctance, inability or poor preparedness for this (Manuel-Navarrete and Gallopín, 2012; Parkhill et al., 2015), or their fellow members' lack motivation for change (Lambrechts et al., 2017).

To be more precise, only in two of the five categories of articles, i.e., novel work practices and professional sustainability mediators, we were able to find clear cases of worker agency. However, one must be careful when drawing broader conclusions based on this, due to both the rather small number of articles and the fact that in many of the articles, the agency of workers was not the object of the original research. Future research should better deal with this issue and bring out new ways of how work organisations and workers can improve their capacity to contribute to the transition into low-carbon production, and how workers can be better involved in these processes.

Much of the previous ST research has concentrated on climate change mitigation and the role of technology in this process. Emissions reductions are urgently needed in agriculture, housing and energy production, and the work of these sectors was often discussed in the reviewed papers. Our findings highlight how STs can impact workers in different industries, including the service sector. Future analysis should be broadened to cover multiple economic sectors, since, due to several interconnections and multi-regime interactions (Konrad et al., 2008), the effects of transitions will increasingly cross industrial borders with deviating consequences between sectors (Dolata, 2009), and eventually involve work in all economic fields, not only in the so-called 'green sectors' (Østergaard et al., 2021).

To answer our second question of what kinds of co-evolutionary change dynamics between STs and workers can be identified, we use the conceptualizations of STs of Geels (2014) and Bögel et al. (2019) to outline the nature of change between workers and STs, as seen in Fig. 2. This illustration is based on the findings of the research review and above-mentioned scholarly work. Even though the reviewed articles did not use this conceptualization of STs presented in Fig. 2, we regard this illustration useful in discussing our findings in the context of previous ST research, and in locating workers in socio-technical systems, and in this way to direct future research in this area.

With Fig. 2 we aim to show that one way to better integrate workers in ST research is to use industry regimes as a conceptual framework for examining in-industry action. Actors in industries, such as workers and work organizations, impact and get impacted in the complex course of actions i.e., sustainability transitions. By opening the black box of the industry regime and the actors within, we can improve our understanding of the complex interactions affecting the preconditions for holistic transitions toward sustainable production. The figure is by no means intended to be all-inclusive; there may be more co-evolutionary change dynamics between actors in industries than illustrated in this figure.[2]

According to the conceptual framework presented in Fig. 2, the interplay between STs and workers can take shape in variety of ways. The arrows in the figure depict the co-evolutionary interactions between workers and other actors in the industry regime and its external environment. Workers interact with each other and within their work organizations and other occupational communities, such as networks or projects. Workers and their work organisations and professional communities also interact in varying degrees with stakeholders in the external environment such as customers, suppliers, non-governmental organisations and policymakers. Changes initiated by actors within the industry regime or its external environment may embody as niche innovations that challenge the path-dependant rules, norms, practices, shared belief systems and mindsets of the industry regime. Some workers can act as intermediaries that move between the levels in the figure, even connecting with other actors in their external environment, and in this way influencing habitual regime elements. Such illustrations connect the findings of our analysis with previous ST research by demonstrating how workers' actions can contribute to the de-structuration of the regimes via changes at work, or, alternatively act as obstacles to STs in regimes by old accustomed work practices. Next, we discuss these interactions in more detail with references to previous research and examples from our findings.

Interactions between workers and work organisations or professional communities

Sometimes workers are affected in STs from the top down, i.e., from actions taken by their work organizations or occupational communities. This dynamic was manifested in the findings ('novel work practices'), for instance, as a diffusion of sustainability from educational programmes of the organisations into teaching work (Lambrechts et al., 2017) or managements' guidance toward environmentally friendly practices in the workplace (Parkhill et al., 2015). In this change dynamic, niche-innovations emerge from the actions of meso-level regime actors as new norms that impact workers.

However, the implementation of such enforced changes in daily practices may not be successful, and workers may have individual or collective agency to reject them (Parkhill et al., 2015). Studies on organisational change have shown how a lack of employee involvement can hamper the implementation of any change process in a work organisation (Beer et al., 1990; Burnes and James, 1995; Coyle-Shapiro, 1999). Some authors of the reviewed papers, such as De Koning et al. (2018) and Lambrechts et al. (2017), stress the importance of simultaneously focusing on both the meso level (work organisation) and the micro level (workers within) in the process of designing or implementing novel sustainable ways of working, and this attention to simultaneous engagement to both levels is also

[2] One such interaction between actors in industry regimes takes place between colleagues who work in a same organization. We would locate this into the micro-level. However, our sample of articles did not disclose such interaction and therefore it is not discussed in this section.

noted by Bögel et al. (2019). In future attempts to organize work more sustainable, practice theories may be useful in supporting such change processes (see e.g. Hargreaves et al., 2013; Sahakian and Wilhite, 2014; Shove and Walker, 2010).

In addition to top-down initiatives, interactions between workers and organizations can also emerge from the bottom-up, as discussed by Dobson (2019) on workers' initiatives. This directionality of change has been a much-studied theme in the pro-environmental behaviour literature (Francoeur et al., 2021; Norton et al., 2015) where the actions, motives and values of workers to work in an environmentally friendly way and initiate change have been investigated. Workers' initiatives can be seen as intermediation that speeds up local sustainability processes in organizations or occupational communities by giving rise to the emergence of new niche innovations, as also observed by Bögel et al. (2019).

Our results reveal several stumbling blocks in making work more sustainable from the bottom-up perspective. As discussed in our findings on 'novel work practices', individuals' willingness to learn and implement novel work practices is not realised unless their co-workers are ready to embrace the ideas (Hemström et al., 2017a). The interdependence between functions and multiple actors in transitions has also been noted by Fischer and Newig (2016), and it illustrates how workers' socially embedded routines can, in some cases, cause inertia for socio-technical change, also noted by Dosi and Nelson (1994). Because single individuals' initiatives usually are not sufficient to lead to disruption in ways of working, change initiatives need to be simultaneously directed to larger groups of workers and supported from the meso level, as also observed by Hoolohan et al. (2021). Thus, workplace could be seen as an 'enabling setting' for shifting work sustainable in collaboration (Süßbauer and Schäfer, 2018).

Interactions between workers and the external environment

Sometimes workers get affected in STs by actors who operate beyond their immediate sphere of work, such as customers, stakeholders of other industries and policymakers. This interplay was discussed in our findings ('niche skills and education'), which showed how new forms of knowledge gradually diffuse from educational programmes to the industry regime, slowly beginning to influence and change accustomed practices rooted in the regime (Dehnavi and Al-Saidi, 2020; Rosenberg et al., 2018). This interaction was also manifested in our findings ('indirect impacts on workers'), which showed how policy changes may have indirect effects on workers (Guibrunet, 2021). Since STs may also affect workers in a top-down manner where workers have no chance to participate in how change takes place, attention should be paid to STs' indirect, delayed, and unintended systemic and far-reaching interactions and consequences to enable just transitions.

Moreover, STs may bring about the exploitation of workers, especially in situations where work is informal and decent legislation is lacking, as observed by Sovacool et al. (2021) and Alonso-Fradejas (2021). According to Wang and Lo (2021), the term 'just transition' refers to multiple situations such as the protection of labour rights, claims for decent job creation in transitions, and requirements of occupational safety and health; all aforementioned uses of this concept were addressed in the reviewed papers. In the future, research on STs should pay increasing attention to these aspects of transitions, especially in cases of imported goods and services and raw materials, which have a crucial role in the realisation of the low-carbon vision and policies, but where involved workers can be lacking decent and formal working conditions, as noted by Neimark et al. (2020) and Kurniawan et al. (2022). Hence, an important prerequisite for any development trajectory to be considered 'sustainable' and 'just' should be such that it does not weaken current conditions for either the environment or workers across different locations.

From the bottom-up perspective, some workers may be able to act as intermediaries, as was shown in our findings on 'professional sustainability mediators'. They can even have an impact outside their own work organisation or professional community and initiate change in larger parts of the industry regime and even outside of it. In this way, some workers can begin to affect other in-industry and outside-industry actors and initiate novelties, if they only have the required resources, networks and visions (Duygan et al., 2019). However, due to the limited number of reviewed articles, it was not possible to draw far-reaching conclusions on what types of worker groups have the best possibility of influencing their external environment. In addition to the general assumption that worker groups with a high level of autonomy and power at work are probably in the most favourable position to play a role in STs, Forssell and Lankoski (2018) and Vankeerberghen and Stassart (2016) highlight the importance of access to learning processes.

In addition to the aforementioned co-evolutionary interplay, at a chosen space and time, the workers themselves may have the capacity and opportunity to reconfigure their own work practices more sustainable. Although many of the reviewed articles discussed frontrunners workers who are driven to make changes to their work discretionally, the studies also showed that even in such cases, workers may have limited opportunities to change their own ways of working, let alone bring about large-scale transformations of work to make it more sustainable, as presented also by Hargreaves (2008). Thus, getting the indifferent and resistant workers, professional communities and work organisations involved in transitions requires other means.

A key question for future ST studies is to find ways of facilitating the diffusion of sustainable work practices to reach an increasing number of workers and work organisations to create sustainable modes to produce and attain climate targets. There is a long tradition of research on organisational learning (Argote, 2011; Easterby-Smith, 2001), and we expect that this field of research can provide multiple tools and concepts in service of such efforts. Further, future research on workers and STs could initiate systematic assessment of different jobs and their impacts on the environment and envision their transition paths, including the needs to reconfigure existing work practices and to adopt novel skills. Fig. 2 helps us identify the key actors in industries and their dynamic relations that should increasingly be paid attention to in efforts to reshape work more sustainable. However, future in-depth studies on the topic also need to take into account other types of factors, such as individuals' motivations, interests, experiences, and capabilities, that cannot be reached with this kind of systems framework. In these efforts, other theoretical approaches may be needed alongside socio-technical system theories. In addition, policies and institutional actors, such as labour unions, also can play a role in changing work sustainable. Future research on workers, work organisations and STs provides a rich and largely uncharted territory for this purpose.

5. Conclusion

The motivation for this article originates from several earlier identified research gaps, such as a lack of social scientific research on work and sustainability (Hoffmann and Paulsen, 2020; Iskander and Lowe, 2020) and a shortage of analysis of actors (Upham et al., 2020; Wittmayer et al., 2017) and micro-level transitions in ST research (Bögel et al., 2019; Köhler et al., 2019). Based on the research review, we created five categories of how STs are connected to workers at the micro levels of industries. Moreover, we demonstrated how the co-evolutionary interplay between workers, work organisations and the external environment may create inner tensions and pressure to change amongst industry regimes, thereby advancing the regime transition toward sustainable production. Until now, ST research has not given sufficient attention to the social aspects of transitions, not to mention the role of workers as actors in transitions. The activities of workers in different economic sectors should be given increased attention in future research on micro-level transitions.

Based on our findings, we concluded that workers can be affected by indirect effects arising from changes in environmental policies or markets, which may weaken working conditions. On the other hand, workers can become employed in new jobs that result from a transition, and in this way, STs may create jobs. In addition, workers can contribute to more sustainable production modes in industries in their daily work practices; some may even be able to influence other actors, such as collaborators or citizens, to engage in more sustainable conduct. However, the results of the review also show how workers can be constrained by their collaborators or work organisations, whose actions externally shape their work practices, and this external influence can hinder the shift toward sustainable work practices.

Moreover, in the discussion, we have presented a novel conceptualisation based on earlier works by Geels (2014) and Bögel et al. (2019) on how change dynamics between STs and workers could be investigated in future research. We returned to the roots of ST research on engineers and organisational change (Dosi and Nelson, 1994), which revealed the crucial role of workers' mindsets and practices in maintaining path dependency. Even though most of the reviewed studies focused on the work of highly educated specialists, we assume that investigating the practices, rules and orientations of workers in all occupations—including at the shop floor level—is crucial for us to better understand the potential and impacts of STs in different industries. The field of STs and socio-technical systems would therefore benefit from future research focusing on workers within the industry regimes.

Finally, our findings underline the fact that STs are social processes where humans are at the centre. However, since the climate emergency accelerates, adjustment to green and decent jobs and sustainable work practices and production modes is needed more than ever. At the same times as STs in work advance, claims for decent work and just transitions must be kept on the policy agenda, amongst formal and informal workers alike. Research is one of the means to provide support for workers and organisations in meeting related major changes.

CRediT authorship contribution statement

Fanni Moilanen: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Tuomo Alasoini:** Methodology, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The data used in the research review is available in Web of Science and Scopus databases.

Acknowledgments

The authors would like to thank Paula Kivimaa, Arho Toikka, Jonathan Köhler, Arja Ala-Laurinaho and three anonymoys reviewers for their valuable comments on previous versions of this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eist.2022.100685.

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