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Shaping Learning Pathways in a Transitioning Sector: A Focus on Solar Jobs in South Africa

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ABSTRACT

The solar energy sector plays a critical role in South Africa's energy transition, especially as it is one of the country's fastest-growing renewable energy sectors. It is envisaged that this growing sector will create numerous jobs in the short-, medium-, and long-term for intermediate-level skills development and will serve as an important access point for youth into the green economy. Although there is a strong aspirational intent for youth employment in the solar sector, due to the sector's rapid fragmented emergence and newness, little is known about the transitioning experiences of entrants, the nature of the available pathways, and the connections between education and work. In this paper, we analyse the learning and work transitioning of individuals in the solar sector, the nature of the occupational labour market, and the emerging provisioning landscape. As a newly emerging, rapidly evolving field of practice, education and work systems must pay attention to experiences of transitions, so we build an understanding of the factors that enable and constrain access to learning opportunities and learning pathways in green sectors, and how these emerge and come to be constituted. We use learning pathway stories of solar employees to understand the dynamics of learning and work transitions, and desktop analysis of the educational and occupational systems that support the solar sector, to help us explore the complexities associated with learning pathway construction, articulation, and efficacy in systems of educational provisioning within a growing green sector. This helps us to raise systemic disjunctures and offers possibilities to enhance inclusive learning pathways for the solar sector. In a context where there is limited empirical evidence of youth experiences in the solar sector, this study hence contributes to highlighting some critical issues that need attention to enable the creation of seamless transitions into green jobs especially in emerging sectors. It illuminates the institutional procedures essential for ensuring efficient and operational systems of work and learning for the solar sector and the broader low-carbon transition.

1 | Introduction

The energy transition has gained momentum over the past few decades due to enhanced climate change impacts such as droughts and floods which call for more environmentally sustainable modes of production (including energy), a reduction in the cost of renewable energy technology (especially solar), and the social and economic benefits that a transition to renewable energy has to offer. Solar energy has been adopted by countries such as Germany, Brazil, India, and China because it is one of the cleanest forms of energy and has extensive availability (IRENA and ILO 2024). In Africa, South Africa is one of the highest carbon emitters due to a dependence on coal for energy. At the same time, South Africa has made enormous commitments to a just energy transition, that ensures a focus on cleaner energy systems while ensuring that the current workforce is not

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left behind and that vast employment opportunities are created (PCC 2022; The Presidency 2023), with the solar photovoltaic (PV)[1] sector being positioned as one of the main sectors to create jobs.

Within South Africa, there is a 45.5% unemployment rate among young individuals (aged 15–34 years), against the national average of 32.9% in the first quarter of 2024 (StatsSA 2024). This makes creating viable options for youth employment a critical priority. Against this background, environmental and green sectors like solar are being prioritised as key economic drivers and areas of employment for the youth. Subsequently, the notion of seamless learning pathways into these new economic sectors has become an escalating conversation.

Despite this prioritisation of green sectors, as important growth points for youth employment, Ramsarup (2017) has argued that the skills system responses to the green transition have been ad hoc, inadequate, fragmented, and reactive. This reactive skills development provides inadequate learning pathways into existing and newly emerging green jobs. She further argued that investigating the nature of learning pathways helps to create better flow within education, improved connections between education and work, and improved development and use of skills at work. Hence studying learning pathways helps to bring many parts of the system into direct relationship with each other and thus helps us to raise questions on how qualifications and curriculum provide for educational progression.

Several authors have recognised that various professions are experiencing a heightened sense of transition (Evetts 2009; Sawchuk and Taylor 2010; Fenwick 2013). They all raise the critical need for education and work systems to pay attention to experiences of transitions. In the context of understanding 'real learning pathways' within the growing solar sector, the traditional supply and demand approach was insufficient. The paper hence aims to analyse the learning and work transitions of individuals in the solar sector. We argue for trying to understand the transitions people are making as an important lens in constructing the nature of the learning pathways as it provides wider systemic articulation concerns, both structural and systemic insights.

The paper is divided into three sections. The first section frames some of the literature on learning pathways within green transitions, and the next section presents some of the learning pathway stories and elicits some of the emerging findings. The third section then surfaces systemic insights and explores what opportunities for change they present for change in learning pathways in the solar PV sector.

2 | Learning Pathways and Their Role in Transitioning Sectors

Evans and Furlong (1997) highlight that over time international research has utilised four metaphors to define the phases through which research and policy have explored youth transitions namely, (1) 'niches', (2) 'pathways', (3) 'trajectory', and (4) 'navigation'. Pathways have been the most widely utilised in policy and practice and have served as an influential organising construct.

Learning pathways refer to an education-work transition which Raffe (2014, p. 177) defines as 'the sequence of educational, labour-market and related transitions that take place between the first significant branching point within educational careers and the point when and if young people become relatively established in their labour-market careers.' In a study by Harris et al. (2006), 'learning pathways' were interpreted as a 'journey of learning'. Their research expanded notions of pathways and challenged the idea that the pathway analogy is a 'deterministic notion' with a set trajectory. Rather, the study highlighted that pathways are 'continuous' and should be seen as a series of stepping stones, making the trajectory 'fragmented and discontinuous'. Another highlighted feature of pathways was direction—pathways lead somewhere, although where are often not known or understood, and sometimes they change direction. In reflecting on the complex patterns of movement, Harris et al. (2006, p. 3) conclude that pathways are not linear and seamless, but rather "stepping stones, zigzags or lurches".

Wheelahan (2009, p. 6) further outlines two important purposes of learning pathways, both of which are relevant to the present research. Firstly, pathways increase the effectiveness and efficiency of education systems—this, according to Wheelahan (2009, p. 6), means that individuals need to be able to move between 'different types of qualifications and different occupational sectors with ease', to reduce time and costs to individuals and governments. The second purpose is linked to equity and social inclusion, 'pathways aim to provide opportunities for disadvantaged groups in society' (Wheelahan 2009, p. 6). Pathways are thus an important mechanism to redress issues related to widening the participation in education and training by students from disadvantaged backgrounds, which is relevant for South Africa's transition to a more just and sustainable society. Wheelahan (2009) further argues that putting pathways at the centre of an education system helps to bring many parts of the system into direct relationship with each other and thus helps us to raise questions on how qualifications and curriculum provide for educational progression. Central to the framing of the study was the idea that 'pathways need to be premised on continuity and complementarity if they are to support educational and occupational progression' (Wheelahan 2009, p. 6).

Current learning pathway research traditions however emphasise individuals' experiences and events they undergo during their learning progression. Tracer studies and education-work transitions are two examples of this kind of research. This kind of research however fails to account for underlying causes, which are linked to the environment, the systems that underlie education provision, and to social change more broadly (Lotz-Sisitka 2009; Schudel 2012).

We, therefore, take cognisance that once research on learning pathways moves beyond the individual, a key known sociological problem of the relationship between macro and micro arises, giving rise to the examination of larger systems or societal patterns. This approach is neither entirely individualistic nor completely determined by structural factors. Applying this approach to the question of learning pathways we show that

individuals actively shape their learning trajectories within the constraints posed on them by systemic conditions of possibility. More specifically, individuals engage in transition practices within several systemic constraints such as job availability, qualifications and training opportunities (or lack of), and the environmental (climate change) and social conditions (sectoral and work changes) they find themselves in.

3 | Methodology

A qualitative study was developed focused on employees in two segments of the solar value chain: the installation, and operations and maintenance segments. The paper is framed around an empirical study of the real career stories of eleven solar employees. The career stories were developed following in-depth interviews and an analysis of curricula vitae. Table 2 provides snapshots of the learning trajectories of the solar employees. This was supplemented by systems analysis of the occupational and qualifications systems and interviews with key stakeholders. A total of 19 participants were interviewed, this included industry experts, training providers, policymakers and government departments, employers, and community representatives.

We utilised a multi-layered analysis to analyse the stories. The first layer of analysis tried to understand the chronology and states of transitions, the second layer examined the entry points and the motivation for entry into the sector, and the third layer focused on enablers and constraints.

This was supplemented by a study of the clusters of occupations we were able to surface. We analysed these into occupational family clusters to show occupational progression and articulation options. These clusters provided information on potential occupational progression pathways. This was complemented by a study of points of articulation in current educational provisioning, which helped to map solar provisioning.

3.1 | Discussion of Findings on Learning Pathways

The findings are reported across three levels. First, we show the nature of occupational and educational progression within the solar sector and how this relates to the occupational network and the education and training landscape. Secondly, we present snapshots of the career stories of eleven employees representing five occupations in the sector as an important lens to surface the multiple entry and exit routes, enablers, and barriers. Lastly, we unpack the emerging systemic insights, where we emphasise what is missing in the learning pathways and suggestions to strengthen and inform structured solar learning pathways.

There is a long list of emerging and transitioning occupations across the different segments of the solar value chain, as represented by Table 1, which shows occupations that surfaced in different parts of the solar value chain.

We identified five occupations that are integral to the implementation of solar PV in the country, and that provide accessibility at an intermediate level. These occupations include solar installers, technicians, technician assistants, commissioning technicians, and electricians. These occupations are mostly centred at the installation and operations and maintenance segments of the value chain. The five occupations perform

TABLE 1 | Solar PV occupations.

	Manufacturing/ assembly	Installation	Operations and maintenance	Decommissioning and end-of-life
Solar PV	• Mechatronics technicians • Electricians • Welders • Glaziers • Toolmakers • Production operators/assembler • Production process controller	• Solar PV technician • Solar PV installer • Solar PV mounter • Electrician • Electrical Assistant • Energy (battery) Storage Installer • Construction supervisor • Construction plant operator • Crane operator • Roofer • Carpenter	• Solar PV technician • Electrician • Energy efficiency technician (energy audit technician) • Energy performance certificate practitioner	• E-Waste operations controller • Waste electrical and electronic equipment (WEEE) manual dismantler

Source: Wits REAL 2024.

related responsibilities and tasks (Wits REAL 2024; Friedman et al. 2011). Ideally, solar installers install solar panels and related structures such as inverters and batteries, and then the electricians connect the structures to electrical systems. Technician assistants on the other hand provide support during installation and maintenance, while technicians handle system planning, installation, maintenance, and troubleshooting. Commissioning technicians then commission the systems through inspecting, testing, and verifying connections against standards and regulations. However, we found an overlap in job tasks and roles across the identified occupations.

The priority occupations are focused in the short term on those needed to lay the foundation for deploying the technologies into the market. The quantum of the skills needed and the localities in which they will be in demand will require deeper analysis and proactive tracking over time. In the medium- to long-term, a more detailed analysis of skilling and reskilling will be needed to assess what emerging industrial role-players in the upstream manufacturing and assembly of the technologies will require. This uncertainty results in unclear occupational progression pathways as pertains to the vertical career moves an individual can make, the skills, and the educational requirements. However, we found that the South African solar sector, while offering opportunities for green jobs, faces inconsistencies in the alignment of occupations. The data hence reveals poor knowledge of the systems of practice at the intermediary occupations level and poor occupational differentiation of solar occupations. Discussions at practice level reveal that there is as yet, a poor knowledge of the scope of occupations, hence they are often mapped incorrectly. According to Freidson (2001), it is important to understand occupational specialisation. He further describes occupational specialisation as 'people performing only the bundle of tasks connected with a defined productive end in an occupation' (p. 18). To map the work of occupations, Freidson argues that one must 'clarify the mental/manual distinction and refine our conception of work and specialisation' (p. 24). This requires an adequate conception of the different kinds of knowledge and skills that are used to guide the performance of work. Clear occupational differentiation enables a sector to plan and plot clear connections within occupational families; it enables better human resource practices in terms of career pathing and enables the collection of coherent labour market information. In summary, the job roles are not well defined, there are labour supply and demand mismatches, and occupational progression challenges.

The analysis of the education and training landscape indicated two clear issues, there is a strong short-course culture emerging, and provisioning is dominated by private providers. These issues posed educational and occupational progression limitations. Wheelahan et al. (2022) make a similar argument regarding micro-credentials, indicating that they are often viewed as easy fixes to occupational progression when in fact several dynamics are at play that a micro-credential cannot fix: social structures and power dynamics, workplace expectations, and inequalities, and knowledge requirements for a field of practice. Further adding to these limitations, we found that the courses offered by the private providers were found to be expensive with respondents indicating that they could not enrol for courses that would enhance their careers if the companies they worked for didn't sponsor them. The course offerings were further reactive and rushed in nature, which Corcoran and Wals (2004) warn affects long-term skills development and career progression, due to a lack of focus on foundational and expanded knowledge needed for specialisation (Shalem and Allais 2018). Furthermore, the limited focus by public providers on solar-related training, especially Technical and Vocational Education and Training (TVET) colleges, has an impact on the accessibility of young people into the sector at an intermediate level. The TVET colleges were reportedly under-resourced, with trainers seemingly being unprepared for the solar sector, and producing a varying quality of graduates (even for traditional programmes such as electrical engineering), impacting the fluidity of educational and occupational progression. In addition, solar provisioning tends to be concentrated in the metropolitan areas in the Western Cape and Gauteng provinces despite provinces such as the Northern Cape and Free State being flagged as regions with significant solar energy generation capacity. This therefore isolates the rural communities where a lot of solar projects are being deployed and where training interventions are urgently required.

The discussion above highlights some of the fault lines that exist in institutional pathways. Most of the training institutions and the industry currently do not provide a clear route for educational and occupational progression, with minimal guidance on the education, forms of training, and career progression linked to the solar sector. The short course offering lacks a sustainability element, with no clear indication of how an individual can traverse the solar energy sector, or how one can acquire more stable employment. This therefore speaks to the lack of a strong disciplinary knowledge base associated with short courses and TVET institutions (Shalem and Allais 2018), which is needed to allow individuals to transition across roles and adapt to sectoral shifts. Further, the learning pathways are not designed with an understanding of the network of jobs, but rather to individual roles. This limits the ability of learners and subsequently employees in the solar sector to gain transferable and adaptable skills that enhance sustainable employability and career progression (Ramsarup 2017). What therefore comes to the fore is that the knowledge of pathways to facilitate mobility in the solar sector is superficial. To deepen the knowledge of learning pathways we tried to gain a deeper understanding of the 'real' life pathways that exist and have been followed by employees in the solar sector. What then emerged is a lack of a clear career and educational path or structure to guide the development and progression of individuals at the intermediate level within the solar sector.

3.2 | 'Real' Life Stories of Solar Sector Employees

Career stories were developed for eleven participants across five occupations including solar installers (five employees), solar technicians (three employees), and one solar technician assistant, commissioning technician, and electrician. We made the decision to use career stories, fully cognisant of the critiques against using retrospective data and the limitations of how and what people relate their stories to (Fenwick 2013). Career stories were however necessary within this study to enable an understanding of how people crafted the emergence of a green

job within a new and emerging sector within undefined pathways. The stories as highlighted in Table 2 below showed that employees followed varied learning pathways into the solar sector. This was the case even for those in similar roles such as the solar installers. Despite the differences, all of the installers, two technicians, and the commissioning technician either had or were planning to obtain a solar PV green card, which is a quality assurance certificate that shows that people installing solar systems can meet industry standards and comply with safety regulations.

Most of the stories reflect a combination of technological advancement, economic factors, and social influence as key reasons for youth entry into the solar energy sector. IRENA and ILO (2024), similarly note that technological advancement is a key driver for job creation in the solar sector globally, especially linked to manufacturing, construction, and installation. For the South African context, however, employees indicated that the pervasive load-shedding issue in the country motivated them to seek employment and business opportunities within the solar sector. Familial influence also played a crucial role, as some individuals highlighted entering the solar energy sector through connections with relatives already working within the sector. Economic factors further shape these decisions, with limited job opportunities in other industries making the solar sector an attractive option for stability and growth. Notably, entrepreneurial aspirations drove some individuals to gain experience in solar energy to start their businesses or engage in subcontracting activities. Lastly, external circumstances, such as the economic fallout from the COVID-19 pandemic, pushed some individuals into the sector after experiencing job losses in other industries.

We further found from the career stories that there was an interrelation between formal and informal learning in the solar energy sector. This was evident from the diverse pathways taken by employees. Many employees entered the sector with formal qualifications, such as diplomas and certificates in electrical and mechanical engineering which provided foundational technical knowledge. Some individuals pursued additional formal training through short courses, such as solar installation and working at heights, to enhance their skills. However, informal learning also played a significant role in shaping the careers of the employees and providing practical training. Informal learning was mainly through on-the-job training, mentorship, and self-directed learning. Furthermore, workplace experience was identified as playing a crucial role in skill acquisition, as many employees transitioned from roles in electrical work, construction, and other fields into the solar sector, learning informally through direct exposure and mentorship. The integration of informal and formal learning is particularly noticeable in cases where employees often learned new skills by working alongside experienced professionals, adapting to evolving industry demands, and conducting independent research to fill knowledge gaps. While formal education provided essential technical foundations, practical application often required informal learning experiences, demonstrating a dynamic relationship between structured training and hands-on industry exposure. These observations are consistent with Sawchuk and Taylor who argued that to understand the range of complexity of learning and work transitioning throughout the life course, we need to recognise 'learning and experience throughout its full range of variation' (Sawchuk and Taylor 2010, p. 1).

Employees however encountered a range of challenges in their educational and occupational progression. A major concern lies in the precarious nature of employment, as many jobs are project-based rather than permanent, leading to financial instability and prolonged unemployment periods. Financial constraints further served as a challenge, particularly in affording necessary training programmes such as the Solar PV Green Card, creating barriers to skill development and career progression. The gap between theory and practice emerged as an additional challenge, with many employees feeling unprepared for real-world tasks due to the lack of hands-on training in academic programmes especially from the short courses and the universities. Technical challenges are also faced, amplified by the rapid evolution of solar technologies, requiring continuous upskilling, which is not easily accessible. The absence of structured internships exacerbates this issue, depriving employees of crucial hands-on learning opportunities. Lastly, limited mentorship and guidance within the industry were noted to hinder career development, leaving employees to navigate complex work environments with minimal support.

The career stories hence indicate that the solar learning pathways are ad-hoc and unplanned, with most employees manoeuvring through the solar sector due to chance encounters with people in the sector, influence from family, and exposure from friends. The nature of the learning pathways, therefore, foregrounds the complexity related to acquiring the necessary skills and knowledge for the emerging solar sector, highlighting the importance of having inclusive and accessible structured training programmes to accommodate multiple entry and exit routes for individuals with different educational and professional backgrounds. The pathway stories in essence indicate that transitions are increasingly fragile and exclusionary and that the number of 'stepping stones' required by youth to secure a labour market position is multiplying.

It is therefore evident that the type of pathways that are emerging are ad hoc, unclear, and lack systemic visibility and accessibility at an intermediate level. The educational offering is fragmented with a range of short courses with different content being offered. Some of these include PV mounting, working at heights, PV green card, and solar design and installation. The employees interviewed therefore appeared not to understand the exact training they needed to enter or advance in the sector. Some obtained one or two short courses, while others did not acquire any solar training, and others gained multiple short courses. On the other hand, some of the participants felt that pursuing courses such as first aid would give them further prospects in the sector. As a result, occupational progression was similarly unstructured and constrained.

3.3 | Unpacking the Systemic Insights

The findings have shown that there are direct consequences of unclear pathways including restrained mobility and progression, skills mismatches, inefficient education systems, and

TABLE 2 | Overview of employee career stories.

Employee	Story
Solar installer 1	They have a diploma in electrical engineering from a University of Technology. They did their apprenticeship in a solar company. They then got a job as a solar installer in another solar company, a role they have worked in for the past 3 years. They did not receive a lot of practical training at university and hence they went through a lot of work-based learning. They then went to a private training centre where they got their solar photovoltaics (PV) green card and a working at heights certificate.
Solar installer 2	Started with a Bachelor of Science in computer science. They worked as an Information Technology (IT) administrator for 2 years. After their contract ended, they enroled for an electrical certificate through the influence of their family. They then did a 5-day solar installation course at a private training centre and got a job as a solar installer. They plan to obtain a solar photovoltaics (PV) green card.
Solar installer 3	They first obtained a diploma in electrical engineering from a TVET college. They then got a 3-year apprenticeship at an electrical engineering company. They then got a job as a solar installer in a solar energy company, where they have been working for the past 4 years. They did not receive any solar related training and learnt on the job. They plan to get a solar photovoltaics (PV) green card in the future.
Solar installer 4	They dropped out of a law course after 2 years and became a general worker in a solar company, where they got a bit of insight into how solar works. They then moved to another solar company as a general worker, and this company sent them for a 6-month solar installation training programme, and they became a solar installer. They have been working in the same company for 4 years. They enroled for the solar photovoltaics (PV) green card but did not pass the course and they plan to enrol again in the future.
Solar installer 5	Trained as an electrical engineer in a college but did not complete their trade test to make them a certified electrician. They then started working as an electrical installer at a solar company, they went for solar installation training at a private college, and they then became a solar installer. They went for the PV green card training, but did not write the assessment. They are currently working on an artisan recognition of prior learning (RPL), and then they will apply for their trade test (formal assessment to receive certification).
Solar technician assistant	They completed their fitting and turning engineering diploma from a TVET college in 2017. They did a short course in hydraulics and conveyor belt maintenance. In 2018, they secured an apprenticeship at a manufacturing company, where they trained as a fitter and turner artisan for four years, qualifying in 2022. In early 2023, while searching for employment, they came across a job posting for a solar technician assistant position (current job). Although the role required training in electrical engineering, their background in mechanical engineering and technical skills enabled them to qualify. They were hired and received theoretical training at the workplace, with the practical component provided through hands-on experience on the job.
Solar technician	They have worked for 3 years in the solar sector. They first worked in a security company as a security guard and as a waiter at a bar. Then they got a job as a general worker at a solar company, and the company then sent them to a private college where they obtained a Solar PV certificate. They were then promoted to a solar installer. They got a job as a solar technician in another company. While in this company, they also received workplace-based training on installing inverters. However, they were retrenched in January 2024 and are hence unemployed. They plan to get a solar PV green card certificate and continue to work in the solar sector.
Solar technician	They started with a certificate in civil and building construction from a TVET college. They first got a learnership at a construction company and then got a job as a junior foreman at the same company and later got promoted to a foreman. They became unemployed during the COVID-19 pandemic. In 2022, they applied for a job thinking it was a construction company and only realised during the interview that it was a renewable energy company. They got the job as a solar technician and continue to serve in that role. They received some training in electricity and the solar PV green card from a private training provider. They received training from Original Equipment Manufacturers (OEMs) on equipment such as inverters and batteries at the workplace.

(Continues)

TABLE 2 | (Continued)

Employee	Story
Solar technician	They first started working as an assistant technician in a solar company, after completing a 6-month solar installation course. They then got a Solar PV green card. They came across someone starting a new solar company and they were interviewed. The company was impressed by their experience, and they were made a solar technician team leader immediately.
Commissioning technician	They obtained a diploma in electrical engineering from Vaal University of Technology. They also did short courses in legal liability and hierarchy while they were at university. They then got a job in cathodic protection (preventing corrosion of gas water pipelines). They were then recruited by their project manager who had a solar company, where they became a technician. They then changed companies and became a commissioning technician (current role) due to their electrical engineering background. Their role as a commissioning technician requires a Wireman's License, which they completed in 2024. They will soon be enroling in a project management course at the University of South Africa (UNISA) because they want to become a site or project manager. They plan to get a solar PV green Card so they can open their own renewable energy company.
Electrician	Has a diploma in electrical engineering from a TVET college. They then completed their trade test and became a certified electrician. Their friend working in the solar sector invited them to work for them in 2019 for a week, and that is where their interest started. They were then called to work at a solar company where they started as a trainee for 6 months. The company provided structured in-house training on solar PV systems, particularly focusing on inverters. After this experience, they secured a position at another solar company as the technical support. Currently, they are a freelancer, offering technical/electrical support to solar companies. They are also pursuing a Wireman's License, which will enable them to issue Certificates of Compliance (COCs) for electrical installations.

enhanced exclusion from economic opportunities. The first direct consequence, restrained mobility, and career progression resulted from the lack of clear structures to support the reskilling and upskilling requirements of the workforce. This constraint was reflected by 36% of the participants who all entered the solar sector with an electrical engineering background, and had very minimal upskilling support, often having to learn on the job and through self-teaching. The restrained mobility and progression mean that individuals entering the solar sector, especially at low and intermediate levels are often unable to realise higher wages or take on more work responsibilities. Further, due to the volatile nature of the construction and installation phase of the solar value chain (where most of the emerging jobs lie), employees are exposed to precarious work (Stock 2021). This indicates that despite the policy tools like the National Qualifications Framework NQF or Recognition of Prior Learning (RPL) there is a disconnect between local institutions and forms of provisioning at local levels which has created a situation that has hindered a collaborative systems approach to individualised transitions and reflects poor local implementation of pathway systems and hence benefits to rural economies. All of which impact the creation of permanent and decent entry-level learning pathways and livelihood opportunities.

The second direct consequence, skills mismatches, results from insufficient skills provisioning which for the solar sector are reactive and job specific, making employees less versatile. The skills system is not proactive and systemic in its approach to supporting the opportunities created by market growth in the solar sector, which is consistent with other studies (Ramsarup 2017; Rosenberg et al. 2020). We found that the skills system, especially as relates to emerging green sectors such as solar energy, is largely reactive and fragmented. Solar occupations are scattered, extremely poorly differentiated, and are not visible across levels of skill, showing unclear connections to higher and lower skill levels. This reveals unclear knowledge of the systems of practice at intermediary occupation levels in the solar sector, leading to poor occupational differentiation. The existing skills mismatches have hence led to increased levels of underemployment.

The third consequence is reflected in an inefficient education system that does not prepare graduates for the solar sector, the existing curricula in TVETs for example have not adapted to the renewable energy landscape, training infrastructure is scarce, with students seemingly unprepared for the world of work. A further indicator of how uncoordinated the solar sector is is reflected in the dominant short course culture, with their emergence reflecting a targeted rapid skills expansion approach which is being driven largely by private providers. This therefore shows that unclear learning pathways have a negative impact on the development of the solar sector and the workforce. Lastly, the unclear learning pathways in the sector subsequently exacerbate existing inequalities, in a sector where inequalities already exist, that is, access to opportunities by rural communities, gender segregation, and unfair conditions for lower-skilled workers. Pearse and Bryant (2022) similarly argue that there are numerous labour challenges in the renewable energy sector, including solar. They highlight gender and racial inequalities, minimal and unequal opportunities for rural communities, low-quality jobs especially for lower-skilled workers, and insecure and unstable jobs particularly at the construction phase. We, therefore, argue that these labour

conditions are strongly influenced by unclear learning pathways and that with a deeper understanding and clear structuring of learning pathways in the solar sector, more sustainable and inclusive green jobs can emerge.

The highlighted direct consequences, we note, are further constrained by some key systemic elements. Firstly, the courses offered to the participants in this study are specific and enable individuals to be absorbed within the sector although in very limited and specific roles. This is often because of complex regulatory frameworks and the procedural steps associated with accreditation and the formalisation of qualifications, resulting in private providers working to close the gap regarding training, standardisation, and quality control as a response to the rapidly expanding skills needs of the industry as the skills system is so slow and reactive. However, the training courses then become extremely expensive, thus limiting access. Furthermore, skills planning is marked by a haphazard, reactive approach to preparing for green work, where mechanisms to gather labour market information are based on current skills needs and are then being used to plan for future skills (Allais 2022). This constraint is exacerbated by the rapidly changing sector. Our findings are in alignment with Rosenberg et al. (2020) who highlight that skills planning has limited anticipatory capacity and inadequate coordination, as well as the absence of a focused, contextually appropriate approach to skills development. Several studies have noted the ineffective functioning of intermediate-skill pathway options in South Africa (Kraak 2008; Perold et al. 2012). This lack of coordination hampers the creation of 'seamless' learning pathways in the sector, and the ineffective functioning of existing pathway options.

We now turn to the second core element—labour market precarity. The solar energy learning pathway career stories tell us that the nature of the learning pathways at the work streams and job levels are characterised by work precarity. The solar sector has an absence of social protection linked to job insecurity. While the sector can create a significant number of jobs (hundreds to thousands), these are often short-term (6–24 months), and low-skilled jobs linked to the construction segment of the value chain. However, after construction and installation, very few individuals have access to permanent employment. Sawchuk and Taylor (2010) referred to these as low-quality 'stepping stone' transitions. Highlighting that once the low-quality 'stepping stone' had been navigated and participants had received a formal contract, work conditions were often very challenging including long hours and low pay. Kraak citing Lauder and Brown also emphasised the issue "… is not the creation of low skills work in itself, but how routes out of such work can be created and protected" (Lauder and Brown, as cited in Kraak 2008). Post construction, labour re-integrates into the job-seeking category. Further, the scale of the sector is currently insufficient to absorb all employees transitioning from affected industries such as coal mining. This situation is exacerbated by the absence of social protection measures such as employment benefits, health insurance, housing assistance, and so on, leaving many workers facing job insecurity and without adequate support during this transition. This is additionally exacerbated by a policy and or regulation absence—as construction companies are not obliged to provide training (upskilling or reskilling)—as a key strategic intervention mechanism geared towards skills development. As such entry-level skilled labour is entrapped into the treadmill of construction and installation and job precarity.

The lack of policy coherence is the third element which empirically is manifested in weak commitment from political leaders who have the influence to steer the transition of the energy sector, enhance public engagement, and acquire and allocate resources to subsequently ensure a just transition through effective skills development, reskilling and upskilling at all education and workforce levels. Turnheim et al. (2015) note that sustainability transitions (such as the transition from coal to solar) require a multifaceted, multi-level approach to governance in which policies across different sectors complement each other and a more nuanced explorative stance to social, economic, and technical change is adopted. However, we find that the absence of policy coherence has led to energy-related policies that are fragmented, contradictory, and misaligned. This incoherence has further resulted in regulatory uncertainty. The planning of skills in South Africa tends to take a highly static and aggregated approach (Allais 2023; Allais and Marock 2020), restricting the ability of the skills system to provide young people with meaningful pathways to employment and career progression within emerging green and digital sectors, and different geographical localities.

From the emergent data, we put forward potential strategies to strengthen learning pathways and provide structure to the progression of education and occupations in the solar sector. Firstly, developing a coherent, demand-led strategy for skilling. There is an apparent need in the country to conduct a detailed mapping of the demand for solar skills across geographic localities and the institutional capacity and requirements to deliver on these at a localised level, including resourcing and accreditation. This can support more targeted interventions to gear up skills institutions (particularly TVET colleges) to deliver on these skills (whether for reskilling or upskilling). The mapping of solar skills will rely on a coherent and industry-accepted set of occupations with clearly defined skill sets and articulation pathways. These occupations should reflect the emerging and evolving reality of the sector and ensure that all roles are factored in. Included in these efforts is supporting the increase in the quality of educational provisioning by conducting a systems-led series of pilot programmes to work with TVET colleges, businesses, and Sector Education and Training Authorities (SETAs) to upgrade and support as well as bridge into work and ensure learnerships and certifications. This will serve to upskill and support TVET lecturers/infrastructure, support mentorship and work-based learning, and ensure collaboration across various industry players to increase impact and future-proof qualifications in recognition of the fast-changing technology landscape. Basic institutional structures and protections could play a role in improving the transition experiences of individuals in the labour market (Livingstone 2004; Sawchuk and Taylor 2010)

Secondly, we propose the support of expanded and coherent RPL to enable bridging interventions to aid in entry into the pathways but also progression. This is important for the solar sector learning pathways, and a just transition because it acknowledges and values the skills and knowledge that

individuals may have acquired through informal and non-traditional training programmes. By recognising RPL, we can facilitate the entry of a diverse range of individuals into the solar sector, including those from marginalised or disadvantaged backgrounds. The actions highlighted above can enhance the inclusivity and diversity of the workforce and ensure that valuable skills are timeously provided.

4 | Conclusion

While this paper analysed the educational and occupational progression of individuals in the emerging solar sector and established the nature of the learning pathways necessary for understanding the systemic alignment required for a just transition, it was limited by a narrow scope of respondents and segments within the solar value chain. We recognise that studying the trajectories of workers in the solar sector over an extended period will enhance our understanding of the learning pathways. Despite this limitation, this study utilised a multi-level focused approach that provided substantive insights. The findings revealed that both educational and occupational progression in the solar sector were unsystematic and reactive. This was particularly evident in the dominance of short courses designed to meet the demand for specific jobs, the inadequate response at the TVET level, the lack of support for employees in the sector, and the limited evidence and opportunities for vertical progression. There are flaws in the education system that create career progression hurdles. Training programmes lack a foundational solar energy (and renewable energy) base that prepares and enables individuals to advance across different roles. There are limited structures for upskilling and reskilling workers entering the solar sector, along with an overall lack of career signposting. The learning pathways, as such, are unsystematic and haphazard, with skills development being fragmented. Furthermore, solar provisioning appears disconnected from the primary skills system; thus, the pathways do not facilitate a smooth transition for new entrants, those in informal education, and the workforce transitioning into and within the sector. Moreover, instead of reinforcing a homogenising and normalising focus on transition processes, these career stories illustrate the need for a more critical and differentiated consideration of needs and local contexts, especially in new and emerging sectors.

In this paper, we therefore demonstrated that, given the newness of the solar sector, occupational contexts are evolving, and individuals are faced with unique challenges with transitioning compared to more established fields, through the use of a learning pathway analysis we were able to surface a deep understanding of educational and occupational progression in the sector and potential strategies to enhance effective education to work transitions that ensure inclusivity at intermediate level. We were able to show that first, the skills system is not systematic; it consists of reactive and fragmented provision. Qualifications and training opportunities are not articulated to allow seamless progression. Second, there is regulation absence and many of the jobs available are short-term and characterised by work precarity. Third, the sector is characterised by an absence of political will and policy coherence. Fourth, skills planning is marked by a haphazard, reactive approach to preparing for green work. What is then needed is strategic systemic collaboration amongst skills system actors to foster clear progression pathways that enable the labour force to advance solar careers and stabilise the sector. This would ensure that all workers and communities, especially those affected by the decline of traditional industries like coal mining, have fair and equitable opportunities to participate in and benefit from the growing green economy.

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Endnotes

[1] Solar Photovoltaic (PV) refers to technology that converts sunlight into electricity, using various components such as panels, electrical wiring, mounting systems and battery storage (Parida et al. 2011).

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