education sciences

MDPI

Article

Two Stories and a Metaphor: A Qualitative Study of Mid-Life Women's Re-Entry into STEM Education

Saima Salehjee * and Mike Watts

Department of Education, Brunel University London, London UB8 3PH, UK; mike.watts@brunel.ac.uk
* Correspondence: saima.salehjee@brunel.ac.uk

Abstract

This paper explores and showcases the return of two middle-aged women to science, technology, engineering, and mathematics (STEM) learning, education, training and professions. We use the lenses of transformative learning theory and intersectionality to explore STEM identity development among our participant women in midlife, despite being 'leaked out' of the so-called STEM pipeline. We employ a qualitative phenomenological research design, conducting narrative interviews and employing thematic analysis to identify key themes for discussion. The implications derived from this small-scale study (n = 2) suggest the need for further research that may potentially be of particular interest to scholars, STEM industries and policy-makers (i) to recognise and act upon stereotypical, inequitable and one-sided views of the 'STEM pipeline', primarily those associated with gender and age, (ii) to acknowledge, appreciate and showcase midlife women's entrance into STEM, thereby benefiting their own personal and professional STEM identity development, and their contributions to the STEM community, indeed to society more widely, (iii) to fund and create informal and community-driven STEM opportunities for middle-aged women to re-engage them with STEM and (iv) to re-think on the limitations proposed by the STEM pipeline metaphor and to focus their attention to a motorway junction metaphor, in which women enter and leave the STEM carriageway at many different points along the way.

Keywords: midlife; STEM; transformational learning; identity; intersectionality; narrative interviews

Academic Editors: Amber Simpson, Laurinda Leite and Luís Dourado

Received: 5 December 2025
Revised: 20 May 2026
Accepted: 25 May 2026
Published: 2 June 2026

1. Introduction

There are several-decades-long demands from governments and industries worldwide to develop workforces with the potential to support and build scientific and technological economies (Metcalf, 2010; Camilli & Hira, 2019). Meanwhile, the necessary scientific and technological skills are widely reported as being inadequate, the 'supply chain' short-lived, all leading to well-established discussions of STEM skill shortages and the impact of people leaving STEM industries (Smith & White, 2022; Huyer, 2015). One key recommendation from policies and practices is to develop these scientific and technological skills in schools and support this throughout children's education and professional development—with the intention of retaining these young people within the STEM pipeline through to adulthood (Smith & White, 2024, 2025). Consistent leakage from this 'STEM pipeline' has been widely reported, involving especially the underrepresentation

of girls and women in STEM education and careers. This begins with lower aspirations of schoolgirls to pursue STEM subjects beyond school science, resulting in lower numbers of women in STEM education at university level, and so, very few women scientists, technologists, engineers and mathematicians continue with a STEM career (Makarova et al., 2016). Women are also reported to 'leak out of' this unidirectional STEM pipeline even after securing a STEM profession (for example, Almukhambetova et al., 2023; Park, 2023).

Although progress in the recruitment and retention of women in STEM has been evident in recent reports (British Science Association, 2020), it remains slow, and gender underrepresentation remains notable. For example, compared with men, women in the G20 countries constitute only 35% of STEM graduates and 22% of the STEM workforce (UNESCO, 2024). Zooming in on the UK over the last three decades, there has been an increase in the number of female students compared to male students accessing higher education, although the underrepresentation of women in the STEM workforce persists, and wage discrimination and the paucity of women in senior positions are still alive and well (Savic, 2019). For example, '27.6% of the core STEM workforce, representing over 1.4 million women across the UK—an all-time high …. It's positive to see an upward trend in several areas, but we should remain cautious; these increases are slight …, and still way off gender parity in STEM' (WISE, 2024, np). This gender parity is important, as scientific and technological advancements are hindered by the limited involvement of women's knowledge and skills in the sector (Bell, 2009; Jones, 2020).

The above reports from the British Science Association, UNESCO, and WISE, along with many similar ones, provide a platform for examining gendered underrepresentation and parity. Still, these are limited to representing a unidirectional STEM pipeline, aligning with the folklore parable of the 'leaky STEM pipeline', which describes how people, especially women, are lost from a STEM production line; this is so much more the case for women than for men (British Science Association, 2020).

This pipeline route from STEM education to STEM professions is primarily viewed as achievable for those with high STEM capital; in other words, people with family or societal opportunities in STEM industry are most likely to persist and advance in STEM professions. However, we view these interrelated concepts as inequitable assumptions. First, it assumes who can and cannot continue to be successful in the long run; as in our previous studies, we discussed that ethnically minoritised British women (who are stereotypically viewed as unable to persist in the STEM pipeline) have succeeded in STEM education and professions (Salehjee & Watts, 2023). Second, people's progress through this ideal STEM pipeline is not always linear for all, with only one starting and ending point, limited to well-known STEM professions, and free of failures (Skrentny & Lewis, 2022). Third, the literature suggests that when people, especially women, exit the STEM pipeline at a particular life stage, they seldom return. For example, Speer's (2023) findings suggest the maximum fallout rate among women is leaking before, during, and after college-level studies (Speer, 2023). And some studies indicate the further fallout after the twenties (British Science Association, 2020). So, the focus is on 'plugging' (Gregor et al., 2023) and 'fixing' (Almukhambetova et al., 2023) the pipeline at various phases of educational and professional lives. For example, STEM training programmes are advertised, such as the STEM ReCharge programme (UK Gov, 2024), and the UK Government funding offers for women who have left the industry due to caring responsibilities (UK Gov, 2023). But the metaphor for plugging the leak of a unidirectional pipeline is still central to these training and funding programmes, where leaking out is viewed as a disadvantage, and there is no clear indication of the women's demographics taking advantage of (or not) these programmes, any limitations associated with recruitment of women into these programmes, and whether (or not) there are any long-term impacts of these programmes on women's re-entry into the STEM industry. The intention of this paper is not to evaluate

the successes or failures of government training and funding programmes, but to understand how leaking out of STEM education and/or professions impacts women's personalised journeys in re-entering the STEM industry. Hence, we are keen to learn about the barriers, challenges, opportunities, and privileges these women experience when re-entering STEM after a considerable period, i.e., in their mid-life.

The existing literature has identified a gap in data sets on women in STEM regarding their intersectional characteristics, including age groups, ethnicity, race, social class, religion, and other factors (House of Commons, 2023). This paper focuses on the intersections of gender and age because, to date, we have found little literature examining their interplay in women's STEM re-entry. Although our focus is on gender and age, we are open to any emergent social categories that our two participants, Maddie and Nina, have shared with us. Our empirical study is limited to two White British middle-aged women; therefore, we intend not to generalise the findings to all middle-aged women STEM returners; rather, we see this research as a springboard for future large-scale empirical research on middle-aged women's re-entry into STEM from diverse backgrounds. Aligning with the gap in the literature on women's personalised journeys and our intentions of showcasing two stories to support our explorations, the theoretical underpinning of this paper is focused on the discussions of transformative learning as a 'process of becoming', in other words, a process that showcases the formation and transformation of self-Identity, here STEM identity, during the mid-lives of women. Moreover, using the concept of intersectionality, we will explore how the formation and transformation of STEM Identity intersect with age, gender, and other identities that support our participant women's re-entry into STEM. In this way, we propose a theoretical underpinning on the development (formation and transformation) of STEM identity and the role of transformative learning and intersectionality in this development. Therefore, we look to address two broad questions:

- How are STEM identities formed and transformed, particularly during the mid-lives of women as they re-enter the so-called STEM pipeline?
- In what ways do age, gender, and other intersecting identities play a role in women's successful return to STEM education and/or professions?

The methodological approach we take in this paper includes qualitative research that presents the individual lived experiences of our two middle-aged participants, Maddie and Nina, as they re-enter STEM in midlife. We call these lived experiences 'STEM lives'. Maddie and Nina's STEM lives, along with the identification of key themes, are presented later in the paper. First, we present background on midlife women in STEM and our theoretical stance for this research.

1.1. Mid-Life Women and STEM

There is no universal definition of the midlife period: it is ambiguous in any clear beginning or apparent end. Midlife, or middle age, is commonly defined as ages 35 to 65 (Etaugh & Bridges, 2013) or 30 to 75 (Lachman, 2001). Over centuries, lifespans and age expectancies have evolved in terms of when they begin, what they entail, and what this phase of life implies for individuals and their immediate environment (Hutchison, 2019). For example, Bordone et al. (2020) explore the perceptions of 828 Italians aged 65–74 years. Most of their female participants did not view age 65 as an absolute age that marks old age. Instead, these researchers found that the feeling of being old is 'mainly influenced by events, such as retirement and death of loved ones, hinting at the importance of the social construction of ageing in addition to its biological dimension' (p. 1669). Moreover, phrases such as 'forever young', 'timeless', 'ageless', and 'ageing gracefully' further support the blurred boundaries between the start and end of midlife. In other words, biological ageing of individuals is not the only predictor of ageing in adults; aspects of how individuals feel

and perceive the self across different spaces and places also determine the ageing process. However, in social media and mainstream platforms, midlife is often associated with an inequitable stance of midlife crisis—including, for example, financial stresses, menopause-associated concerns among women, and signs of physical and cognitive ageing. Hence, suggesting a closure of the STEM pipeline, or even that it is impossible for women to re-enter it.

In the UK, middle-aged women comprise the largest share of the female population, with Millennials and Generation X taking the lead (ONS, 2023). Compared to men, however, women in general constitute only 29% of STEM and STEM-related professions (UK Gov, 2023) and 27.6% of the core STEM workforce. One reason for this gender gap is that more women than men take career breaks from STEM employment, including maternity, health or stress-oriented breaks, especially after their twenties, and seldom return (British Science Association, 2020). As "women are more likely than men to interrupt their careers to fulfil childcare responsibilities, 47% of UK women in STEM had career interruptions, compared with 17% of men, according to a 2022 survey by STEM Returners" (UNESCO, 2024, p. 37). Some 75,000 individuals, mainly middle-aged women, do seek to return to STEM fields following a career break (UK Gov, 2023), where "66 STEM Returners partners with STEM organisations to run short-term paid returner schemes as well as providing career coaching, upskilling and mentorship opportunities" (UNESCO, 2024, p. 37). Our aim is to explore this seemingly paradoxical picture of women leaving and attempting to re-enter various STEM and STEM-related disciplines (Herman, 2015).

To better understand the challenges faced by adult women who either "never return" or find it "hard to return" to STEM fields (Jackson, 2011; Jarvis, 2008), it is essential to explore their lived experiences, with a particular emphasis on both formal and informal STEM learning. Despite the significance of these experiences, as mentioned earlier, there is a notable lack of literature that specifically addresses the lived experiences of middle-aged women in STEM. These are women who may have left the STEM pipeline at different stages—some departing early, i.e., just after school science and others, leaving later in life, i.e., after a higher education qualification or even after a profession in STEM, but who subsequently return (or are in the process of returning) to STEM-focused education, learning, and training during their midlives.

1.2. Transformative Learning

There is a growing body of work (for example, Elliott et al., 2023; Montgomery & Fernández-Cárdenas, 2018; Zoller, 2015) focused on improving STEM education among young and older adults. Our focus, however, is less on improving pedagogies in formal STEM education and more on exploring the personalised learning and practices among women, in this paper, Maddie and Nina, who re-enter STEM education and professions. In doing so, we draw on Mezirow's theories of transformational learning, looking for the 'disorientating dilemmas' and the 'a-ha' moments that herald change, new directions and new possibilities. Mezirow was interested in people's worldviews and what leads them to reappraise these: he describes transformative learning as learning that transforms problematic frames of reference to make them more inclusive, discriminating, reflective, open, and emotionally able to change (e.g., Mezirow, 1997, 2000). There is no doubt that change can be uncomfortable and disorienting, but in transformative learning, exploring, trying out, testing and working through new perspectives are keys to success.

Mezirow showcases transformational learning either through a single crisis or through the accumulation of (smaller) disorienting dilemmas (Illeris, 2014; Salehjee & Watts, 2020). These changes, rapid or slow, can act as 'life-turning' moments that occur for particular reasons within the personal needs of individuals and their immediate environment (Illeris, 2014). For example, in our own work, it is not uncommon to hear

expressions such as 'It is now important for me to engage with …', 'It is high time for me to …', 'I want to prove to my friends that I can…', 'I have never—but now I should….' (Salehjee & Watts, 2020, 2023). These disorienting dilemmas lead to periods of self-realisation and critical reflection on frames of reference shaped by different events, circumstances, and experiences—followed by self-recognition of shared experiences (Mezirow, 2000). In our case, we are interested in capturing some of these 'moments of reflection', of Maddie and Nina, as a basis for discussing the formation and transformation of self-identity towards STEM—what we call 'STEM-identity development' (Salehjee & Watts, 2020, 2023).

Lear (2017), for instance, in Midlife Awakening: An Emergent Transformation of Self, looks at developmental changes in women's personalised transformative experiences. Lear believes such developmental changes emerge within "third age" women as "personal growth and self-realisation of a more complete, balanced and fulfilled self" (p. 277). Like Lear, we believe transformative learning in STEM happens in an individual's everyday life. This transformative learning in everyday life is mainly 'free-choice learning', a self-directed, subjective process that occurs predominantly outside formal educational settings (Falk & Dierking, 2012; Falk & Needham, 2013). Moreover, as with Deleuze's and Guattari's (1987) notion of 'rhizomatic', free-choice learning has no specific order, structure, start or end point (Cormier, 2008), grows freely without specific direction, and focuses on 'assemblages' drawn from diverse learning experiences. These experiences vary for different people as individuals agentically engage in a range of learning processes. They are processes that evolve and are shaped by acquired experiences, self-motivation, and individual needs (Lian & Pineda, 2014).

1.3. Intersectionality

Intersectionality is a broad sociological theory used as the 'key analytical framework through which feminist scholars in various fields talk about structural identities of race, class, gender and sexuality' (Cooper et al., 2015, p. 1). Collins and Bilge (2020), for example, use an intersectional lens to critically analyse macro-level sociological themes: relationality, social context, social justice, complexity, and inequality bestowed by society's established powers. A smaller body of literature, especially in adult learning and education, situates intersectionality at the individual level, drawing on personal 'lived experiences' from a variety of social and cultural backgrounds (Groener, 2011; Salehjee & Watts, 2023; Rubenson & Desjardins, 2009). In doing so, scholars in the fields of equality, equity, inclusion, and diversity tend to use intersectionality to explore the personalised lived inequalities experienced by adult learners. This helps to understand better macro-level power relations, inequalities, and marginalisations as directly experienced by adult learners (Groen & Kawalilak, 2019; Shields, 2008). In a similar vein, we aim to explore the intersecting personalised lived experiences of our two middle-aged participants, Maddie and Nina. Moreover, these personalised, intersectional lived experiences could entail personalised transformative experiences leading to transformative identities, as the intersections of age, gender, ethnicity, race, and social class identities are not static; rather, identity formation occurs and transforms at and across these intersections (Jeong & Väyrynen, 2018). Within our exploration of midlife 'STEM lives', we are interested in exploring STEM identity development (formation and transformation).

2. Materials and Methods

We use qualitative phenomenological research to collect and portray our participants' STEM lives. This approach supports our intention to "dwell with the subjects' descriptions in quiet contemplation' (Parse et al., 1985, p. 5). A phenomenological approach provides a platform for detailing, in this case, the lived experiences of Maddie and Nina

(pseudonymised names), including the factors that shape their midlife decisions and choices to return to STEM learning, education, training and professional practices (Wilson & Chaddha, 2009).

Using opportunistic and snowball sampling, our inclusion criteria are that they all are (i) British-born women aged between 30–60, (ii) from any part of the UK, (iii) belong to any ethnic, racial, social class and home backgrounds, (iv) left STEM at any stage but re-enter during the midlives, i.e., between the age frame of 30 and 60. Factors outside these inclusion criteria included people who identify as men or women and are under 30 or over 60. This work is part of ongoing research on middle-aged women in Britain who return to STEM through formal and informal means. Currently, we have recruited only two middle-aged women, Maddie and Nina, who are represented in this paper. Therefore, as mentioned earlier, the presentation of a small sample (n = 2) is not generalisable to all middle-aged women re-entering STEM, but these two stories provide a platform for discussion on the STEM pipeline metaphor and assumptions associated with middle-aged women.

Our research employs both deductive and inductive approaches. Deductive as the theoretical underpinnings of transformative learning and intersectionality in relation to STEM identity development were used to design the narrative interviews and conduct an analysis of this study. And inductive, because the empirical evidence provides new insights into the personal lives of Maddie and Nina, such as discussions of motherhood, non-linear STEM trajectories, and the importance of informal learning in their STEM lives.

We conducted narrative interviews with Maddie and Nina individually through an hour-long online interview and asked them to recall and recount their personal experiences related to their STEM learning, education, training and profession. The three key interview questions were: (i) about their previous and current entry, exit and re-entry into STEM through formal and informal means, (ii) to recall the transformative triggers and moments of self-reflection of their abilities and routes to STEM—influenced by certain events, occasions and circumstances associated with the leaving and re-entry into STEM, (iii) their self-recognition and identification with living a STEM life. We let Maddie and Nina answer the questions above in detail, without our interference. At reasonable intervals, we inquired further of our participants, only to clarify or elaborate on what they had told us. Prior to this interview, during the recruitment stage, we had a 20–30-minute conversation about their involvement in STEM, educational backgrounds, and current professional activities.

The analysis of our narrative data employed six steps. The process of the analysis steps and ways these six steps are validated is discussed below:

1. Snapshots

We have written snapshots, i.e., an overall short description of Maddie and Nina, individually and in third-person voice, including their biographical information and a description of Maddie and Nina with regard to the research questions on (i) the formation and transformation of STEM identities and (ii) the role of age and gender in this formation and transformation. In step 4, these snapshots were revised to include Maddie's and Nina's direct quotes to support our interpretation, and these revisions were then validated by the participants.

2. Thematic analysis (1)

For validation purposes, we individually identified codes and themes from Maddie and Nina's transcripts and later discussed them to finalise the themes. Examples of codes and finalised themes are provided in the tables below (Tables 1 and 2). Moreover, during the interview stage, we did not specifically ask participants about the role of gender, age, social class, ethnicity and other social factors in their STEM lives- this was to eliminate our

influence on data collection and subsequent analysis. Therefore, the data represents only the social factors revealed by the participants.

Table 1. Maddie.

Codes	Themes
• Maternity leave (short Ex) • Raising a young family, full-time house mother- career break (Ex/RE). • COVID lockdown (Ex/RE). • Interaction with primary school children (RE). • Interaction with her own children (RE).	Triggers and reflections to exit (Ex) and re-enter (RE) in STEM learning, education, training, and professions. (Aligns with disorienting dilemma and critical reflection phases of transformative learning)
• Childhood affections for animals. • Rural inhabitant. • SPCA animal carer. • Mother of two children. • Responsible adult	Self- recognition and self-identification with STEM
• Becoming a primary school teacher. • The ability to spread her passion for animal care to the younger generation. • Extended knowledge of wildlife and STEM.	STEM identity development (formed/transformed) and middle age. (Aligns with self-recognition with a transformed frame of reference, and identity development phase of transformative learning)
• Informal STEM talks with children. (IF) • Local community STEM team. (IF) • STEM educational talks. (F/IF) • Teacher training course. (F) • Animal care education. (F)	Shared experiences: free-choice learning and practices (Formal (F)/Informal (IF)) (Aligns with self-chosen practices to share experiences with others, concept of transformative learning)

Table 2. Nina.

Codes	Themes
• More interested in English and History—formal education (Ex), exited from STEM at 16. • Zero-hour contract—surveying post (RE). • Opportunity to write a piece for Rolls-Royce about her engineer father (Ex). • Working with on-site scientists and engineers (RE & Retention).	Triggers and reflections to exit (Ex) and re-enter (RE) in STEM learning, education, training, and professions. (Aligns with disorienting dilemma and critical reflection phases of transformative learning)
• Trumpet for older women • STEM learner enthusiast • Recognition of what is achieved and the worth of it. • Being an older woman in a man's STEM world counted as a minority. • Jack of all trades	Self-recognition and self-identification during midlife (Aligns with self-recognition with a transformed frame of reference, and identity development phase of transformative learning)
• Qualified aerobics teacher—helping friends and the community. (F/IF) • Self-learning on the job, Google searches and reading articles (IF). • Attending courses (F).	Shared experiences: free-choice learning and practices (Formal (F)/Informal (IF)) (Aligns with self-chosen practices to share experiences with others, concept of transformative learning)

3. Thematic analysis (2)

We have used inter- and intra-categorical complexities (McCall, 2005) to collect and analyse the interview data. This has specifically shaped the research design through existing analytical categories of age and gender. Simultaneously, we have been open to any

emergent categories that the participants shared with us. We first individually identified codes, then combined them to align them with social factors, for example, age, gender, social class, and ethnicity, identified in the transcripts. Examples of these codes and intersections (as themes) are provided in the table below (Table 3).

Table 3. Codes and themes with a focus on intersectionality.

Participants	Codes	Theme: Intersectionality
Maddie	• Motherhood • Scottish town of Dumfries, with a working-class background. • A nurse mother, qualified but did not go to university. • Father worked as an automobile worker with no qualifications. • Growing older with more responsibilities (as a mother), more experience and more freedom to choose.	Mother (gender) and inhabitants (residency). One of the parents has a science (nursing) background. Women and middle-aged (gender and age).
Nina	• A middle-class White English family and an engineer father. • Raising a young family- sacrificed a full-time job and a promoted post. • Being an older woman in a man's world counted as a minority.	Social class and an engineer father. Motherhood and profession (gender and professional in stability) Gender and Age

4. Reviewing and amending step 1

After steps 2 and 3, we revisited the snapshots (step 1) to validate our interpretations and amend them as required. At this stage, we also included direct quotes from the participants to support our interpretations. After this step, transcripts and snapshots containing direct quotes were sent to the participants for member checking- suggested changes were made. For example, Maddie asked us to include details about her children's ages and the varied influence of COVID on her professional pursuits. And Nina, asked to change the term "interesting life" from one of her quotes to "rich life", and emailed us the explanation, which we included in the study.

5. Selecting and organising the events

The selection and organisation of events presented in this paper were mainly chronological, as they occur in the participants' lives, and also based on the importance participants assigned to them. For example, Nina started her story with the written piece she wrote about her engineer father rather than with her current work at the Environmental Agency. So, we mentioned the importance of her written piece in our analysis. For validation purposes, the chosen sequence of quotes presented in this paper was sent to the participants. Both Maddie and Nina gave us the go-ahead to present them in the order that helps the reader understand their stories.

6. Thematic analysis (3)

Next, Maddie's and Nina's STEM lives were compared and contrasted, which led us to identify three overarching themes focused on middle-aged women returning to STEM. The three themes include: intersectional transformation, midlife STEM learning, and midlife STEM identities. In doing so, the theoretical underpinnings of this research were revisited and supported by the literature.

Maddie's and Nina's individual STEM lives (steps 1–5) are presented in the next section of this paper. Step 6, which discusses the overarching themes, is presented in the discussion section of this paper.

There is no denying that power-positionality is at play. We are both considered to be—appropriately or otherwise—expert scientists and sources of authoritative answers and explanations. We are evaluators, validators and eventual publishers of participants' responses, albeit through permission-granted and ethically approved Brunel University London's research procedures. The participants were informed that (i) they have read and understood the participant's information sheet, (ii) they are free to withdraw from this study at any time and without any reason, (iii) their choosing not to participate or withdrawing will not affect them in any way (iv) their names, exact living locations and organisation names will be anonymised unless the participants would like to declare them. In addition, participants were asked whether they agree (or not) to: (i) have their interview audio and video recorded and discarded just after the transcripts have been obtained and checked for accuracy with them, (ii) the use of non-attributable quotes when the study is written up or published, (iii) the procedures regarding confidentiality have been explained, (iv) store and shared their anonymised data (transcripts) for a maximum of five years with other researchers for use in future projects. Both Maddie and Nina volunteered to take part in this study and agreed to all the above-mentioned statements. In addition to obtaining written consent from our participants, as mentioned earlier, we employed member-checking by sending them transcripts, snapshots, and our interpretations and sequencing of their direct quotes; any changes/modifications requested by Madie and Nina were made in due course.

This study, like other seminal small-scale studies in STEM education, for example, identity research by Carlone and Johnson (2007); Brickhouse et al. (2000), and Avraamidou (2020) e.g., works have provided guidance for conducting small-scale qualitative studies that focus on stories (as cases) from a few participants. We also employ this small-scale, storied approach to qualitative data collection. Though this paper has extensively detailed the data-gathering and analysis process, it exhibits qualitative rigour, which will be of interest to other qualitative researchers seeking to replicate the processes of constructing snapshots followed by a three-step thematic analysis in their own contexts.

3. STEM Lives of Maddie and Nina

3.1. Maddie

Maddie was born and raised in a White working-class home. Maddie and her family have always lived in the rural Scottish town of Dumfries, with her mother a nurse and her father working for an automobile company without any specific qualifications. From early childhood, Maddie demonstrates a strong affinity for and identification with STEM (STEM identity). Neither parent directly influenced her identification with STEM learning or education, nor her professional decisions. But what really influenced her passion and decision to pursue a career in animal care was her early childhood affection for animals, she said, which was sparked by caring for her pet dogs. In addition, her life on a rural Scottish farm gave her the opportunity to "be around farm animals and care for them", which eventually shaped her school and college STEM choices, especially biology, chemistry and mathematics. Over time, the formation of STEM identity, especially Wildlife and animal care identity, grew stronger as Maddie, in her early 20s, completed animal care studies at a university, and straightaway joined the Scottish Society for the Prevention of Cruelty to Animals (SPCA) Wildlife Hospital as a trainee, followed by working as a qualified animal rescue officer for almost a decade. During her time at the Scottish SPCA, Maddie lectured on Wildlife Rehabilitation and Nutrition at a college level.

Maddie's professional passion as an animal rescuer continued throughout her 20s without any breaks. At the start of her 30s, she took maternity leave (a short temporary exit) for her first child, then returned to the SPCA for a few years. That period ended during the 2020 COVID lockdown—and with the birth of her second child at the age of 35. From early 2020 through the summer of 2023, Maddie underwent her first major transformative period in her professional life, leaving her "full-time" and a "very demanding" career in animal rescues to become a full-time house mother. Recalling this period in life, Maddie mentioned:

> I didn't mind growing older; it was kind of just like the more responsibilities of being an adult, being a mother of two children. It was just intense.

While her life took this transformative turn, Maddie critically reflected on her real passion for wildlife and animal care, and for a good five to six months, she engaged in self-reflection on her abilities and explored ways to either re-enter the animal care profession or find alternative jobs that would suit her family life. During this self-reflective phase, Maddie recalled her first interactions with primary school children, giving a talk to them about animal rescue while at the SPCA.

> I made PowerPoint presentations with lots of photos, and I just told all the stories about the different animals that were rescued and anything of interest. And the kids' questions were great! It was like, what was the biggest animal? What's the scariest animal? And they were so enthusiastic because I get so excited when I talk about these things. I think that helps. You know, I could talk about animals all day.

This past event served as a trigger, prompting self-reflection on her abilities, passion and alternative routes to fulfil her passion. In turn, Maddie realised that there is "hope and opportunity to [for her to] provide better lives for animals," and simultaneously deepened her critical reflection on her role in spreading her passion to the younger generation. This realisation was further strengthened by her involvement in teaching her children using family learning resources, as Maddie recounted that, during the enforced COVID lockdown, a local community STEM team sent out educational packs to parents of young children, like her, every week.

> One week, we got bubbles, then we got massive dominoes. Another week, it was finding reflective things and so my children were out looking on their bikes. There was a bug-hunting kit and an explosive kit, which was fantastic. So, my little girl absolutely loved that, and so did my little boy, who liked playing with the bubbles. Yeah, they really enjoyed it all. I helped with the bubble-making because it was a great kit with all the different shapes and things like that, in different sizes to make all the different-shaped bubbles. I questioned and discussed with my children. Why is reflection important? Why do we have it? How does it work? And the dominoes were for like buildings, you know, the big giant wooden dominoes, so you could play dominoes, or you could build them, or you could stack, do whatever. So we're always doing things like that at home. Lego is a big thing in our house, and we do Lego challenges—where we've to build a certain thing. We do that as a family.

Overall, Maddie's STEM identity shifted from specific wildlife to broader STEM knowledge and practices as she went on maternity leave for her first and second children, becoming a full-time mother, amid COVID-related limitations. These limitations in life were viewed as challenges by Maddie, which were used as an advantage to strengthen her STEM identity, as she said,

> My love and passion for STEM grew from my early, specific science knowledge of wildlife to a wider and interlinked form of science, technology, engineering and mathematics knowledge—although it [this growth into STEM] took a different direction.

Moreover, Maddie mentions that the move from a decades-long professional life at SPCA to re-entering university pursuing a teacher training course and a career in primary teaching was not easy, as it was out of her comfort zone:

> Leaving the SPCA and enrolling at university to pursue a teacher training course was a big move. However, I feel I am more useful as a teacher because I have expertise in Wildlife Science and understand the needs of my community, especially children of families who have never attended university. I am more of an insider [now].

As an insider who could be more useful to her immediate community in Dumfries, Maddie pursued a teacher training course while also raising her young children, and her self-confidence allowed her to understand STEM topics better than fellow student teachers, with little or no STEM knowledge.

> If we were ever stuck on STEM topics, we would just Google, but most of the time, my peers consult me to understand the topic. When I was on my placement, I remember my fellow trainees and the class teacher learned from me how to plan and teach friction, so I did a little push experiment with the kids using cars on different materials. And you know the chat the kids were having was unbelievable. They were talking about how the car will move on the foil. If they pushed it gently, it just went straight, but they pushed it too hard. If it's been like soft cardboard that was kind of on a hill, and they realised if they didn't push it hard enough, it would roll back. Minds were just working. And the class teacher learned and appreciated my knowledge when we were sitting, talking about it before and after doing the lesson.

Currently, Maddie is working as a full-time primary school teacher, and both children, her 7-year-old daughter and her 5-year-old son, are in school, and Maddie ensures that the family STEM learning and discussions continue, which are seldom planned and generally occur in a variety of informal spaces, such as local parks, the car, and at home.

> I'm always teaching my own children about animals and things like that, how they should respect the environment that we live in. We do like … going for walks, and parks, and exploring nature with friends. My wee boy is a bit more like me, I think he's a lot more into animals than my little girl. She doesn't mind, but he loves being outside and loves exploring. He wouldn't be afraid to get his wellies and his waterproofs on a rainy day and go jumping in puddles. Actually, before I dropped them off [at school], we saw a rainbow. And the conversation didn't just stop there, they know that if it's sunny and it's been raining, chances are we'll see a rainbow. He knows that it's the sunlight reflected. And then, when you see a double rainbow, it's even more exciting. And they always want to go to the end of the rainbow and see if they can see anything. But then it just keeps moving with you.

So, in traditional terms, Maddie 'leaked out' of the unidirectional STEM pipeline, just after leaving the SPCA career and entered primary school teaching, which is not typically viewed as a STEM profession. All this change was needed from her to be a responsible (middle-aged) adult and mother. However, during this so-called leaking out, Maddie viewed her (i) STEM identity to be strengthened through engaging with a holistic STEM learning (formal and informal) and shared these learning, knowledge and skills with her

own children and immediate community (other teachers, pupils, and their parents) as an insider and (ii) Maddie believes that she did not so much leak out of the STEM pipeline rather "just took a different direction".

3.2. Nina

Nina, Somerset-born, belongs to a middle-class English family, is the mother of three young adults, and has lived most of her life in London. Despite being accomplished in school STEM subjects and having an engineer father, she relinquished those subjects at age 16 in favour of English and history. Here we see an early exit from STEM formal education, and hence the careers followed were mainly in non-STEM areas. Nina has held numerous roles in the early years of her career, including a senior management post at British Airways. She then moved north to Cumbria in her late 20s, left her senior role at British Airways, to start a family. In Cumbria, Nina was offered a senior post, which she had to decline after becoming pregnant with her third child. This senior post required a full-time commitment, so she started with a few part-time, junior-level, low- or no-salary jobs while juggling work–life balance.

> And although I still got a managerial role in Cumbria, it wasn't a senior post, and I ended up accidentally getting pregnant again. It was really difficult then; I mean, trying to find a part-time job in Cumbria. I didn't want to work full-time with three young kids. I actually worked for a while at an occupational health company as an admin assistant and was then offered a surveying post, doing evaluations. It was basically a zero-hour contract and, yeah, I didn't have the confidence to just go straight back in at a senior management level. I did apply for a chief executive officer job but chickened out at the last minute because it just didn't feel like the right time.

Although well-paid, well-positioned jobs were offered to Nina, she decided to turn them down because she believed it was impossible to work full-time while raising three young children. The decision to continue with a zero-hours contract as a surveyor was the first critical transformative move, serving as a stepping stone and a trigger point for Nina to re-enter a STEM-associated profession at the age of 34 and to develop a STEM identity.

Nina is now in her late fifties and has worked as an estate surveyor for over two decades. As a UK Environment Agency Senior Estate Surveyor in land strategy, she works with scientists and high-tech industries to promote sustainable land management. For example, she is currently working on-site with architects, engineers and environmentalists to lead the Thames Barrier land strategy project, aiming to prevent flooding in London, including at the London Gateway port. Unlike Maddie, she has no formal STEM education after the age of 16, and much of her STEM knowledge on land surveying, analysis, management and standard checks of the land was gained on the job. In addition, Nina went to seminars, conferences and CPD programmes which were STEM-focused, and they were self-chosen by Nina out of interest:

> I like getting to the bottom of things and often question things. I mean, it's like with building construction and sustainability and stuff, I've been interested in trying to make buildings more energy efficient ever since I started as a surveyor. Yeah, I remember going to talks and seminars by people—quite early on. The career I'm in is actually very, very wide-ranging. We have to do 20 hours of continuing professional development every year. So, I tend to go and learn about something I don't know anything about. Something interests me rather than just, you know, doing more on evaluation, or whatever.

The desire to learn new topics and skills is not limited to STEM; it also extends to writing and singing skills, which Nina believes support her working life:

> I think I've got a bit of a butterfly brain. Probably I just like learning new things. I had a boss once who thought I was too much of a Jack of all trades. I had just too many interests. But I think that having all those different strands has some relevance to my job. Yeah, I can write, so I can write reports. I can sing so I can stand up and talk to people. So yes, I can communicate.

At various points in the interview, Nina mentioned her gender and age identity that transformed over time, as she views herself as a "trumpet for older women", "an older woman in a man's STEM world", and "counted as a minority", which does not bother her anymore and women dropping out from the environmental sciences profession in 40s or retiring at 60 does not appeal to Nina. As Nina mentioned, more women are entering the surveying profession with an interest in environmental science. That said,

> the number of women of my [middle] age within the surveying profession is quite limited, and I think the statistics show that most women drop out after about 40–45. I feel, in a way, that I must blow a bit of a trumpet for older women. It's interesting, isn't it? In terms of culture? Because, actually, yes, I'm quite unusual, I've been a woman in a man's world for a long time. And being an older woman in a man's world, or even an older woman in the workplace, actually causes disruptions. Yes, I think most people think that by the time you're 60, you're going to be thinking about retirement. And I actually like using my brain. You know, I still like learning things. I do think, yeah, I'm in a minority, and sometimes, it really bugs me. But other times, actually, I've quite liked the fact that I am counted among minorities!

Nina elaborated on the point above about age, noting that she has always been a self-curious person, but she was more able to practice her self-curiosity in her late 40s outside her full-time job. This curious disposition afforded opportunities in life that led her to train professionally as a chef and an aerobics teacher, and to become a writer for *Rolls-Royce Magazine*. One of Nina's most memorable experiences upon re-entering STEM learning was writing for the *Rolls-Royce Magazine*. The editor of the magazine had initially approached Nina, around 25 years back, for a biography on her father, which acted as a second and critical transformative decision of her life, strengthening her identification with STEM further, which made her self-learn about automobile engineering informally and in-depth:

> My father worked for Rolls-Royce as an engineer, helped design the Concorde, and also worked on the Harrier jump jet engine. He became quite a specialist in the Harrier and got an award from some guys in America at one point, which was quite prestigious. And Rolls-Royce Magazine wanted an article about him. So, I wrote about my dad and his work. And then a second one for the Bristol West Country Illustrated, and, actually, that was really interesting. I had to get my head around the technical aspects of what he was talking about and translate it into layperson's language. I mean, obviously, the people reading the Rolls-Royce Magazine would have had a deeper understanding, but for the local magazine, you know, I had to do a sort of translation.

Her self-chosen informal routes to STEM-focused knowledge and understanding are varied and extensive, demonstrating a continuous development of STEM identity that originates from her everyday interests, such as being a keen fitness enthusiast who enjoys running and cycling:

> I like knowing how bodies work. Actually, the other day, my friend was asking how she could strengthen her triceps—and I could tell her. For me, it's not just going out running, but actually knowing what effect it's having on me. It's basically sports science, isn't it? After qualifying as an aerobics teacher, I did a

> summer school a year or two later, called Extending the Fitness Concept. And it was very much about—yeah, different types of stretching, having different effects on muscles. And what's happening in your muscles when you're stretching or exercising or whatever?

Nina is always enthusiastic about the Internet and Google as a support medium for purposeful informal learning in STEM, for example:

> I quite often search on the Internet nowadays. I mean, I've got various books on various subjects, but you know, I do think Google is great. I'll give you a specific example. I've recently had a frozen shoulder, and it got worse….I read about hyaluronic acid and that sort of thing. Then I read several in-depth medical articles and research papers about it. Yeah, I wasn't just reading the chat rooms, I actually found some proper research papers. When I eventually saw the GP, I said to him, "Oh, well, I think I need XYZ", and he said, "Well, I've never heard of that" (Laughs).

Nina's story highlights transformative events in her middle-aged life that led her to pursue STEM-focused learning, education, and professional development, despite having 'leaked out' of formal STEM education at 16. In addition, the mandatory on-the-job training to become a surveyor did not include in-depth STEM learning and educational opportunities. Nina's free-choice learning attitude laid the foundation for in-depth STEM learning, knowledge, and skill-building. So, in general terms, Nina fell out of the STEM pipeline and never returned, as her qualifications and current profession title do not fall under STEM professions. However, her story contradicts this, as she re-entered STEM in a non-linear and non-conventional manner. Moreover, Nina contradicts the ideology that older women's working lives in environmental science, for example, are limited to 45, and their learning lives to 60, further supporting the unconventional re-entry of middle-aged women in the STEM pipeline.

4. Discussion on the Overall Findings

The three overarching themes gained from the STEM lives of Maddie and Nina are discussed below.

4.1. Intersectional Transformation

People's lives, unlike the unidirectional STEM pipeline, are rarely simple, straightforward and direct. We see Maddie and Nina as transformative intellectuals (Giroux, 1988) who shape and change their own lives even as they are familiar with and subject to large-scale social forces around them. Being reflexive in this way entails an ongoing process of looking both inwards towards one's beliefs, preconceptions, and practices, as well as outwards, towards the social world (Giddens, 1984).

Maddie and Nina are both White women and belong to very different households. Maddie always lived in the countryside and came from a humble background, while Nina lived in the city and came from a middle-class family, with her father, a renowned Rolls-Royce engineer. With such a background, people like Nina are viewed in the literature as having much more fertile opportunities than Maddie, who comes from a rural working-class background, and so the interplay of identity and capital (cultural, social, and economic resources) (Archer & Mendick, 2025) would possibly favour women like Nina more than Maddie to remain in the STEM pipeline for long. But this is not the case here, as Nina left STEM at 16, returned to it at 34, and did not mention her social class as a privilege that supported her education, professional decisions, and informal STEM learning. Maddie continued with STEM-related education and a profession until around 31 and returned after a short gap of 4 years into primary teaching, which Maddie believed developed her

STEM identity, in addition she maintained her connection with STEM, which she leveraged from her country life as an advantage and asset in her educational and professional choices and informal STEM learning.

We find Mezirow's (2000) theory of transformative learning useful for understanding what we might call 'intersectional transformation'—the ways that individual lives develop and transform in accordance with, or going against, the 'macro' social forces. Nina, for instance, discussed the gender inequitable reality of society towards which she previously accepted and 'just went with'. However, we see her fighting against this by acting as a role model for older women and reframing her minority status in a more positive light. Maddie didn't specifically discuss gender or age discrimination; rather, she discussed how her rural life influenced her educational and professional decisions to become an animal carer, spreading awareness about animals and wildlife to the young generation and also becoming a primary school teacher, as she wants to be useful not only to her own children but also to the immediate community she lives in. Maddie and Nina never complained about their life circumstances; instead, they reflected on their abilities and other interests and pursued alternative careers, which were uncomfortable and disorienting at the start but supported their work–life balance and eventually helped them develop personalised identities with STEM.

In the cases we discuss in this paper, the micro-changes for transformation, as outlined by Mezirow's theory, are prevalent. For example, Maddie, it meant gaining access to a ready-made audience for her ideas and activities: she was spurred to change by working with primary-age children, believing she could make a greater personal and professional impact through school teaching than through her work with the SPCA. Moreover, Nina was driven toward change in part by her own insatiable curiosity and in part by agreeing to the task of writing in both technical and lay languages, and by seeing that she could achieve it. For both, it was a significant move in their lives; these were personal, self-determined, life-changing decisions.

Similarly, having children was a major factor in both their lives. Maddie and Nina experienced what proponents of transformational learning call a "deep, structural shift in the basic premises of thought, feelings, and actions" (Morrell & O'Connor, 2002, p. xvii), as they grew to understand themselves and their social location as middle-aged women. Maddie and Nina had to rethink their career paths and found alternative routes to pursue careers that suit their families' interests. They both did this without complaint and did not go against the social and cultural backdrop of motherhood, leading to carer disadvantages. However, these stories illustrate how women with children are disadvantaged in the labour market and that their motherhood negatively impacts their earnings and career retention, which can be termed as 'motherhood penalty' (Deming, 2022). For Nina, this could mean struggling to maintain a foothold in the employment market while also raising her family. Maddie clearly felt that the COVID lockdown had been a seminal event, not in itself entirely negative, but transformative for her educational and career choices. Literature on the motherhood penalty in relation to COVID (Dias et al., 2020) could relate to Maddie's story to some extent, but not entirely, as Maddie did not view the COVID lockdown as a penalty, but rather a time where she could spend more time with her children and extend her holistic STEM identity through informal means, as she said:

> [During COVID] my daughter's nursery was really good about sending certain activities to families, and one of them was to make up a 'potion'. At that point, my husband was off from work because of the lockdown, so he took the opportunity to do the back garden—which was a bit like a building site, full of soil and rubble and all sorts. So, lots of nice walks to go and collect things for potions, like grass, seeds, berries, flowers, mud, anything at all, anything at all was good

> to go in the garden when it was finished. She just loved it—we have pictures of her in a little superhero outfit, mixing up potions.

4.2. Midlife STEM Learning: Free-Choice and Rhizomatic

As Ross (2023) points out, learning encompasses a wide diversity of practices. Between our two participants, Nina and Maddie, we can list participatory workplace learning in a rhizomatic, free-choice manner, through seminars and talks, nature explorations, community engagement, writing, mentoring relationships, online videos, museums, galleries, and much more. Biesta (2005) offers a view of learning as

> A reaction to a disturbance… an attempt to reorganise or reintegrate as a result of a disintegration … responding to what is other or different, to what challenges, irritates and disturbs us, rather than as the acquisition of something that we want to possess (p. 62).

Maddie and Nina's confidence and independence in STEM learning gradually formed and transformed the 'frame of reference' or shifts in mindsets, from their viewpoint that they are only experts in particular STEM or non-STEM areas and not confident in the others, to the value of transferable informal STEM learning. We see that confidence and independence in curiosity-fuelled STEM learning seem to have shown progressive STEM identity shifts during their midlives. There are probably many factors at play: the ease of engagement with informal STEM learning aided by Google and the internet (Nina), their self-motivation to support their community grew over time (Maddie and Nina), career breaks that gave them the opportunity to be involved with the community, time to self-evaluate their commitments and life expectations, and part-time jobs (Maddie and Nina).

These progressive shifts in mindsets were cumulative, and some transformative trigger points and life experiences challenged them to try out new roles and actions, such as Maddie engaging with inquisitive questions from primary-school-aged children about Wildlife and animal care, and Nina challenging herself to write her engineer father's biography. These actions build their self-confidence to learn and practice STEM outside their comfort zones, and success was felt in the process and in the outcomes of taking on new, challenging roles, which were reinforced by further learning, planning, and actions. Nina explained her view on STEM success as:

> Professionally, I'd say I'm successful at the moment, because I'm quite well paid, and I've got a good job. I sometimes think actually, I could be more senior. But actually, do I really want to? And I mean. a little example of recent success. And it didn't take a lot of effort, I am now working on one of the most exciting projects I could [for] 2 days a week. Within the environment agency. I'm now working on the land strategy for the new Thames Barrier. which I just think is the most amazing project to be involved with. So I suppose for me. Success is about having a rich life. I don't want to get to my deathbed regretting all the things I didn't do. I do feel the key thing about being human is to experience and learn things, not just plod along. I just felt 'interesting life' sounded potentially a bit negative, whereas 'rich' sounds more positive. Obviously, it's all subjective—some people are perfectly happy with a life which plods along, which is fine (for them!).

4.3. Midlife STEM Identities

Nina and Maddie, as middle-aged women, viewed life as a challenge and used their creativity and imagination to design new midlife STEM identities by discerning alternative possibilities and different ways of living that were more personally rewarding. Both women, as mentioned earlier, recounted vignettes of difficult times, conflicts, and demanding experiences that they reconstrued as challenges for developing new understandings and interpretations. The transformation, for Maddie and Nina, was an inner change in personal integration, fulfilment, and STEM identity development, an incidental outcome of civic engagement (Nina), community activism (Maddie), higher education (Maddie) and informal STEM learning (Maddie and Nina). Implicit learning is an important area of adult learning that needs more research, as the mode of learning described cannot be learned from books, even though it is a fundamental part of identity development in being and becoming at the personal and professional levels.

This paper presents the STEM lives of Maddie and Nina that exhibit a positive, transformative shift in women's STEM identity development during midlife. This positive shift has supported our participants in realising their self-ability in STEM learning and practices and in demonstrating better control of their personal and professional lives. The barriers, such as their biological age, gender, and family backgrounds, associated with these transformative shifts, discussed by Maddie and Nina and in our view, have supported rather than undermined their confidence in challenging stereotypical norms. Nina, as she discusses her own career breaks, dips, and rises in career progression, shares some instances where she went against the grain by strengthening her self-belief- a recommendation for women and mothers of young children:

> I think self-belief. Be conscious of what you've achieved in the past, I mean [as] an example ... once [I] saved Brent Council about a million pounds, which back then was worth more than it is now. And not so long ago, I was talking about this to a friend when I was applying for jobs. And I said, 'Oh, you know, that was a long time ago, do you think it's worth mentioning it?' [in the job application form]. And she said, 'If you'd won a gold medal at the Olympics back in 1990 or 1995, you'd still put it down on your CV!' And I think it's that sort of thing that you have to remember and recognise what you have achieved.

5. Conclusions

In this article, we used the lens of life stories, as STEM lives, to identify what is enacted in the cases of Maddie and Nina. Our work recognises that people make sense by construing theories of the world, of themselves, others, and events as they experience them, with foundations in Dewey's philosophical pragmatism and phenomenological themes. We explored the following questions:

- How are STEM identities formed and transformed, particularly during the mid-lives of women as they re-enter the so-called STEM pipeline?
- In what ways do age, gender, and other intersecting identities play a role in women's successful return to STEM education and/or professions?

The empirical insight gained in answering our first research question, as depicted by Maddie and Nina, has many facets, with a key emphasis on STEM identity development intersecting with motherhood identity. Maddie and Nina, with young families, took on the challenge of supporting their families while remaining engaged and motivated in their career progression. The second emphasis is on midlife STEM development, which complements Lear's (2017) belief that developmental changes, here STEM identity development, emerge within 'third age' women, or during midlives, through (i) self-recognition of their own varied abilities and (ii) self-realisation of the ways they can live a complete,

balanced and fulfilled self through supporting their own personal growth, along with family and work–life balance and their community at large. Third, this development in STEM identity required favourable, transformative life events. These life events demonstrate a progressive, cumulative shift in Maddie and Nina's mindsets, with some transformative trigger points and life experiences challenging them to try new roles and actions. As mentioned above, Maddie and Nina accepted these challenges, which were fuelled by free-choice, informal, and rhizomatic learning in STEM, as explained by Falk, Deleuze, and Guattari, supporting the building of their STEM identity.

The second research question complements our first question on STEM identity development by analysing transformative learning attributes through the lens of intersectionality, as 'intersectional transformation', with a focus on the intersections of age and gender. First, both Maddie and Nina were aware of gender and age inequities, but they took them as challenges by showing transformation in their mindsets, for example, by accepting and progressing as a minority in a man's world (Nina) and taking on the motherhood and personal growth challenge as a middle-aged adult (Maddie). Second, acting on these transformed mindsets, they willingly stepped out of their comfort zones and established careers (e.g., British Airways (Nina), SPCA (Maddie)) to new roles and careers (primary school teacher (Maddie) and Environmental Agency surveyor (Nina)) that were disorienting at the start but necessary for the transformation and, in turn, the development of a transformed STEM identity.

Third, a crucial point here is that Maddie and Nina, in midlife, viewed themselves to be in a 'prime age' phase, when their self-confidence, intelligence, informal STEM learning, and ability to take on challenges are at their peak. In this case, there is also a need to pay greater attention to context and transformative learning, particularly the social dimension and its implications for fostering change. The intersections of age and gender seemed positive for both Maddie and Nina. More research is required, but our small-sample study suggests that progress in STEM does not follow a single path; instead, people take various routes, much like a motorway with many entrances and exits.

Bringing back our discussion on the unidirectional STEM pipeline, while our study is not exactly a rebuttal of the leaky pipeline, we are keen to illustrate the considerable limitations of this overused metaphor and, in our view, it widens the equity gap by ignoring the different, personalised journeys of women and their fluid movement in and out of STEM. Thus, the metaphor has the potential to mislead the policy implications by shifting the focus to the leakage of women at specific points in life, with a high likelihood of not returning to STEM (Stefani et al., 2024). Similarly, the empirical insights from Maddie and Nina's STEM lives contradict the STEM pipeline metaphor as a simple, unidirectional input–output model of STEM education and careers, as they both enter, exit, and re-enter STEM willingly to support their personal and professional lives. As we see Maddie and Nina enter, leave and re-enter STEM across many phases of life, the metaphor might be more like a stretch of motorway between junctions: people, here Maddie and Nina, enter and leave the STEM carriageway at many points along the way. For example, Nina left STEM at 16 because she was not interested in STEM and wanted to continue with English and history. Her initial career choices were in the managerial sector, but she later returned to STEM through her work and involvement in free-choice and informal STEM learning and associated practices. Maddie, for instance, continued with STEM education and profession much longer than Nina, even during the career break phase; she seemed to be involved with informal STEM learning and associated practices and then returned to STEM, in Maddie's view, through involvement with primary school children.

Finally, it is important to note here that both Maddie and Nina are currently working in non-conventional STEM workforce shortage list of careers, as, for example, they do not fall directly into the engineering and technology sectors where women are mostly

underrepresented, but as mentioned by Maddie, teachers with STEM knowledge and skills are underrepresented in primary school teaching, and the literature on the workforce shortage recommends better equipping primary school children with STEM skills and knowledge, which, in turn, can support the development of a stronger workforce (Kotsis, 2024). In addition, as Nina mentioned, women in land surveying are reported to be underrepresented (Greed, 2022). More research on women re-entering non-conventional STEM careers would support our findings.

Further research is needed that is potentially of particular interest to scholars, STEM industries and policy makers and therefore, from this small-scale research, our recommendation is to achieve the following:

- Appreciate, acknowledge STEM identity development among the middle-aged women who can undergo formation and transformation—in a positive direction—because of their freedom of choice in STEM learning and their feeling of better control of their personal and professional lives.
- Empirically research middle-aged women from diverse backgrounds and showcase their personalised STEM identity development through the lenses of transformative learning and intersectionality.
- Scholars and policymakers to reflect on the STEM pipeline ideology by focusing on using a motorway junction metaphor, in which women enter and leave the STEM carriageway at many different points along the way, Because STEM learning does not always stop even when women are on career breaks, in their mid-career, or outside the so-called STEM pipeline.
- Governments and STEM industries to fund and create informal and community-driven STEM opportunities for middle-aged women to re-engage them with STEM, which can potentially lead some of them to consider STEM-related training and a career in the future.

There are limitations to what we infer from our data and analyses. First, although we proposed in-depth qualitative research, our sample consists of only two middle-aged women. Secondly, both women under study were White, although our focus in this study was on age and gender, and the women participants were from different educational, social, and home backgrounds; still, women from diverse ethnic backgrounds have the potential to bring different personalised stories of free-choice, formal and informal learning needs and practices. Therefore, more research on middle-aged women's re-entry into STEM is needed to further develop empirically and theoretically, using the frameworks of transformative learning, intersectionality, and the STEM motorway metaphor, to examine the development of STEM identity among midlife women from diverse backgrounds.

Author Contributions: Both authors contributed to all aspects of the research and writing of this manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the College of Arts, Law and Social Sciences Research Ethics Committee of Brunel University (Reference code: 48409-LR-May/2024-51089-1; date of approval: 1 May 2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data presented in the manuscript were obtained with participants' consent to publication. No further data and materials (e.g., audio recordings) will be available.

Conflicts of Interest: The authors declare no conflicts of interest.

References

Almukhambetova, A., Torrano, D. H., & Nam, A. (2023). Fixing the leaky pipeline for talented women in STEM. *International Journal of Science and Mathematics Education*, *21*(1), 305–324. https://doi.org/10.1007/s10763-021-10239-1.

Archer, L., & Mendick, H. (2025). Becoming exceptional: The role of capital in the development and mediation of mathematics identity and degree trajectories. *Educational Studies in Mathematics*, *118*(1), 119–137. https://doi.org/10.1007/s10649-024-10360-2.

Avraamidou, L. (2020). "I am a young immigrant woman doing physics and on top of that I am Muslim": Identities, intersections, and negotiations. *Journal of Research in Science Teaching*, *57*(3), 311–341.

Bell, S. (2009). *Women in science: Maximising productivity, diversity and innovation*. Available online: https://www.researchgate.net/profile/Sharon-Bell-2/publication/276278575_Women_in_Science_Maximising_productivity_diversity_and_innovation/links/55552ad008ae980ca60ad868/Women-in-Science-Maximising-productivity-diversity-and-innovation.pdf (accessed on 10 April 2025).

Biesta, G. (2005). Against learning. Reclaiming a language for education in an age of learning. *Nordic Studies in Education*, *25*(1), 54–66.

Bordone, V., Arpino, B., & Rosina, A. (2020) Forever young? An analysis of the factors influencing perceptions of ageing. *Ageing and Society*, *40*(8), 1669–1693.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(5), 441–458.

British Science Association. (2020). *APPG on diversity and inclusion in STEM. The state of the sector: Diversity and representation in STEM industries in the UK data analysis brief inquiry into the STEM workforce*. Available online: https://www.britishscienceassociation.org/Handlers/Download.ashx?IDMF=d7899dce-22d5-4880-bbcf-669c0c35bda6 (accessed on 10 April 2025).

Camilli, G., & Hira, R. (2019). Introduction to special issue—STEM workforce: STEM education and the post-scientific society. *Journal of Science Education and Technology*, *28*(1), 1–8. https://doi.org/10.1007/s10956-018-9759-8.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *44*(8), 1187–1218.

Collins, P. H., & Bilge, S. (2020). *Intersectionality*. John Wiley & Sons.

Cooper, B., Disch, L., & Hawkesworth, M. (2015). *The Oxford handbook of feminist theory*. Oxford Handbooks.

Cormier, D. (2008). Rhizomatic education: Community as curriculum. *Innovate: Journal of Online Education*, *4*(5), 2.

Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia*. University of Minnesota Press.

Deming, S. M. (2022). Beyond measurement of the motherhood penalty: How social locations shape mothers' work decisions and stratify outcomes. *Sociology Compass*, *16*(6), e12988. https://doi.org/10.1111/soc4.12988.

Dias, F. A., Chance, J., & Buchanan, A. (2020). The motherhood penalty and the fatherhood premium in employment during COVID-19: Evidence from the United States. *Research in Social Stratification and Mobility*, *69*, 100542. https://doi.org/10.1016/j.rssm.2020.100542.

Elliott, R., Loh, C. G., Psenka, C. E., Lewis, J. M., Kim, K.-Y., Haapala, K. R., Neal, D., & Okudan Kremer, G. E. (2023). Advancing transformative STEM learning: Converging perspectives from education, social science, mathematics, and engineering. *Journal of Integrated Design and Process Science*, *26*(3–4), 393–414. https://doi.org/10.3233/JID-220006.

Etaugh, C. A., & Bridges, J. S. (2013). *Women's lives: A psychological exploration*. Pearson.

Falk, J. H., & Dierking, L. D. (2012). Lifelong science learning for adults: The role of free-choice experiences. In B. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (Vol. 24.). Springer. https://doi.org/10.1007/978-1-4020-9041-7_70.

Falk, J. H., & Needham, M. D. (2013). Factors contributing to adult knowledge of science and technology. *Journal of Research in Science Teaching*, *50*(4), 431–452.

Giddens, A. (1984). Elements of the theory of structuration. In *Practicing history: New directions in historical writing after the linguistic turn* (pp. 119–140). Routledge.

Giroux, H. A. (1988). The hope of radical education: A conversation with Henry Giroux. *The Journal of Education*, *170*(2), 91–101.

Greed, C. (2022). *Surveying sisters: Women in a traditional male profession*. Routledge.

Gregor, M., Dunn, M., Campbell-Halfaker, D., Martin-Fernandez, J., Ferrer, A., & Robinson, S. (2023). Plugging the leaky pipeline: A qualitative investigation of untenured female faculty in STEM. *Journal of Career Development*, *50*(2), 425–444. https://doi.org/10.1177/08948453221101588.

Groen, J., & Kawalilak, C. (2019). Reflections on the adult education professoriate in Canada. *Education Sciences*, *9*(1), 43. https://doi.org/10.3390/educsci9010043.

Groener, Z. (2011, June 8–12). *Adult education, globalisation and inequality in South Africa. Searching for new analytical frameworks*. Adult Education Research Conference, Toronto, ON, Canada. Available online: https://newprairiepress.org/aerc/2011/papers/41 (accessed on 10 April 2026).

Herman, C. (2015). Returning to STEM: Gendered factors affecting employability for mature women students. *Journal of Education and Work*, *28*(6), 571–591. https://doi.org/10.1080/13639080.2014.887198.

House of Commons. (2023). *Diversity and inclusion in STEM, 5th report 2022–23*. HMSO. Available online: https://www.sciencecentres.org.uk/documents/751/House_of_Commons_Science_and_Technology_Committee_Diversity_and_inclusion_in_S_3d7yeCi.pdf (accessed on 10 April 2026).

Hutchison, E. D. (2019). An update on the relevance of the life course perspective for social work. *Families in Society*, *100*(4), 351–366. https://doi.org/10.1177/1044389419873240.

Huyer, S. (2015). *Is the gender gap narrowing in science? UNESCO science report: Towards 2030*. Available online: https://www.researchgate.net/profile/Sophia-Huyer/publication/323402194_Is_the_Gender_Gap_Narrowing_in_Science_and_Engineering/links/5a9496bb0f7e9ba42970cea7/Is-the-Gender-Gap-Narrowing-in-Science-and-Engineering.pdf (accessed on 10 April 2026).

Illeris, K. (2014). *Transformative learning and identity*. Taylor and Francis, Routledge.

Jackson, S. (Ed.). (2011). *Innovations in lifelong learning: Critical perspectives on diversity, participation and vocational learning* (1st ed.). Routledge.

Jarvis, P. (2008). *Democracy, lifelong learning and the learning society*. Routledge.

Jeong, H. W., & Väyrynen, T. (2018). Identity formation and transformation. In *Conflict resolution* (pp. 59–77). Routledge.

Jones, L. (2020). *Women's representation and voice in media coverage of the coronavirus crisis*. Available online: https://www.kcl.ac.uk/giwl/assets/covid-media-analysis.pdf (accessed on 10 April 2026).

Kotsis, K. T. (2024). Obstacles to teaching science in primary school and strategies to overcome them. *European Journal of Contemporary Education and E-Learning*, *2*(1), 223–233. https://doi.org/10.59324/ejceel.2024.2(1).18.

Lachman, M. E. (Ed.). (2001). *Handbook of midlife development*. Wiley.

Lear, G. (2017). Midlife awakening: An emergent transformation of the self. *Journal of Transformative Education*, *15*(4), 277–295. https://doi.org/10.1177/1541344616670264.

Lian, A., & Pineda, M. V. (2014). Rhizomatic learning: "As… when… and if…" A strategy for the ASEAN community in the 21st century. *Beyond Words*, *2*(1), 1–28.

Makarova, E., Aeschlimann, B., & Herzog, W. (2016). Why is the pipeline leaking? Experiences of young women in STEM vocational education and training and their adjustment strategies. *Empirical Research in Vocational Education and Training*, *8*(1), 2. https://doi.org/10.1186/s40461-016-0027-y.

McCall, L. (2005). The complexity of intersectionality. *Signs: Journal of Women in Culture and Society*, *30*(3), 1771–1800. Available online: https://www.journals.uchicago.edu/doi/epdf/10.1086/426800 (accessed on 10 April 2025).

Metcalf, H. (2010). Stuck in the pipeline: A critical review of STEM workforce literature. *InterActions: UCLA Journal of Education and Information Studies*, *6*(2), 21. https://doi.org/10.5070/D462000681.

Mezirow, J. (1997). Transformative learning: Theory to practice. In P. Cranton (Ed.), *Transformative learning in action: Insights from practice. New directions for adult and continuing education* (No. 74). Jossey-Bass.

f Mezirow, J. (2000). *Learning as Transformation*. Jossey Bass.

Montgomery, C., & Fernández-Cárdenas, J. M. (2018). Teaching STEM education through dialogue and transformative learning: Global significance and local interactions in Mexico and the UK. *Journal of Education for Teaching*, *44*(1), 2–13. https://doi.org/10.1080/02607476.2018.1422606.

Morrell, A., & O'Connor, M. A. (2002). Introduction. In E. O'Sullivan, A. Morrell, & M. A. O'Connor (Eds.), *Expanding the boundaries of transformative learning: Essays on theory and praxis* (pp. 15–20). Palgrave.

Office for National Statistics (ONS). (2023). *Estimates of the population for the UK, England, Wales, Scotland, and Northern Ireland*. Available online: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland (accessed on 10 January 2026).

Park, M. H. (2023). *Mitigating the leaky pipeline: Women engineers professional identity development as engineers in the field*. Pennsylvania State University. Available online: https://www.proquest.com/openview/704430ab7750ca81eefd88eaddc7d7d9/1?pq-origsite=gscholar&cbl=18750&diss=y (accessed on 10 April 2026).

Parse, R. R., Coyne, A. B., & Smith, M. J. (1985). *Nursing research: Qualitative methods*. Brady.

Ross, J. (2023). *Digital futures for learning: Speculative methods and pedagogies*. Routledge.

Rubenson, K., & Desjardins, R. (2009). The impact of welfare state regimes on barriers to participation in adult education: A bounded agency model. *Adult Education Quarterly*, *59*(3), 187–207. https://doi.org/10.1177/0741713609331548.

Salehjee, S., & Watts, D. M. (2020). *Becoming scientific: Developing science across the life-course*. Cambridge Scholars Publishing.

Salehjee, S., & Watts, D. M. (2023). *Learning to succeed in science: Stories of South Asian women in Britain*. Bloomsbury Publishing.

Savic, M. (2019). *Over education and hourly wages in the UK labour market; 2006 to 2017*. Office for National Statistics. Available online: https://backup.ons.gov.uk/wp-content/uploads/sites/3/2019/04/Economic-review-April-2019-1.pdf (accessed on 10 April 2026).

Shields, S. A. (2008). Gender: An intersectionality perspective. *Sex Roles 59*, 301–311. https://doi.org/10.1007/s11199-008-9501-8.

Skrentny, J. D., & Lewis, K. (2022). Beyond the "STEM pipeline": Expertise, careers, and lifelong learning. *Minerva*, *60*(1), 1–28. https://doi.org/10.1007/s11024-021-09445-6.

Smith, E., & White, P. (2022). Moving along the STEM pipeline? The long-term employment patterns of science, technology, engineering and maths graduates in the United Kingdom. *Research Papers in Education*, *37*(4), 457–478. https://doi.org/10.1080/02671522.2020.1849374.

Smith, E., & White, P. (2024). Science for all? School science education policy and STEM skills shortages. *British Journal of Educational Studies*, *72*(4), 397–424. https://doi.org/10.1080/00071005.2024.2322964.

Smith, E., & White, P. (2025). Gender, participation and attainment in STEM: A comprehensive overview of long-term trends in the United Kingdom. *British Educational Research Journal*, *51*(2), 802–825. https://doi.org/10.1002/berj.4102.

Speer, J. D. (2023). Bye bye Ms. American sci: Women and the leaky STEM pipeline. *Economics of Education Review*, *93*, 102371. https://doi.org/10.1016/j.econedurev.2023.102371.

Stefani, A., Minor, R., Leuze, K., & Strauss, S. (2024). Empirical challenges in assessing the "leaky STEM pipeline": How the research design affects the measurement of women's underrepresentation in STEM. *International Journal of STEM Education*, *11*(1), 54. https://doi.org/10.1186/s40594-024-00512-4.

UK Gov. (2023). *More women to be supported back into STEM jobs in Government-backed training*. Available online: https://www.gov.uk/government/news/more-women-to-be-supported-back-into-stem-jobs-in-government-backed-training (accessed on 8 December 2025).

UK Gov. (2024). *STEM ReCharge programme evaluation*. Available online: https://www.gov.uk/government/publications/stem-recharge-programme-evaluation/stem-recharge-programme-evaluation (accessed on 8 December 2025).

UNESCO. (2024). *Changing the equation: Securing STEM futures for women*. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000391384 (accessed on 10 April 2025).

Wilson, W. J., & Chaddha, A. (2009). The role of theory in ethnographic research. *Ethnography*, *10*(4), 549–564. https://doi.org/10.1177/1466138109347009.

WISE. (2024). *Workforce data—December 2024*. Available online: https://www.wisecampaign.org.uk/workforce-data/ (accessed on 10 April 2025).

Zoller, U. (2015). Based transformative science/STEM/STES/STESEP education for "sustainability thinking": From teaching to "know" to learning to "think". *Sustainability*, *7*(4), 4474–4491. https://doi.org/10.3390/su7044474.