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# Multi-story building: A montage of STEM success through autobioracy

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## Abstract

This paper presents a montage of STEM success stories, employing phenomenographic narrative research to gather and present people's lived experiences: their 'STEM (life) stories'. We chart the experiences of members of the general public as they meet issues of STEM in their everyday lives and coin the term autobioracy, moving away from autobiography, to capture, analyse and showcase our participants' oral accounts. We showcase three such accounts—Carys, Philip and Mehr—to explore their adult re-engagement with STEM after a long prior period of disengagement, that is, after their formal school-based science and technology education. We explore the ways in which they construct assemblages in their descriptions and explanations of the STEM they encounter. We resist a 'template' method to the interpretation and analysis of participants' STEM stories and adopt instead a montage approach to narrative analysis, presenting oral stories of events and their descriptions logically, not necessarily chronologically, to illuminate the meaning of their complex, often contradictory and unpredictable ways of knowing and understanding STEM. We position ourselves as 'entre-deux' in-between first-person and other-person accounts. Employing autobioracy montage validation, our findings analysed the STEM life stories of autonomy, self-direction, self-aspiration and self-time-lined STEM travellers, who engage in informal STEM learning and enter and leave STEM learning as and when they like. We suggest more empirical research that uses both STEM stories and a construction of montage of these different STEM stories, which senses different pictures and portrayals

of the same phenomenon, here the 'late-onset STEM' re-entry, across different contexts and phases of life. Moreover, this study proposes a motorway system with no single starting or ending point to address the longstanding problematic perceptions of age and formal education limits.

**KEYWORDS**

assemblage, autobioracy, montage, phenomenography, STEM, stories

**Context and implications**

**Rationale for this study:** Critiquing the leaky STEM pipeline metaphor, we present STEM stories and a montage of two women and a man returning to STEM late in life.

**Why the new findings matter:** This study proposes a motorway system with no single starting or ending point to address the longstanding problematic perceptions of age and formal education limits.

**Implications for practitioners, policy-makers and researchers:** The implications of this study warrant further research and are potentially of particular interest to policy, for example, the British Government's recommendations to improve 'the STEM skills pipeline' (UK Parliament, 2025, p. 1). This research will also be of interest to STEM educators and researchers, who can extend their work by employing late-onset STEMers and by adopting or adapting the construction of STEM stories and story montages to critique and address issues in STEM education. Above all, this study will provide confidence and encouragement to the general public to return to STEM even after they have long left STEM education.

## INTRODUCTION

We use our descriptions and discussions of STEM stories to question a pervasive metaphor within STEM education, that of 'the leaky pipeline' (Alper, 1993). The metaphor presupposes a regular standard educational supply system (the pipe) that channels children and young adults into study and employment in science, technology, engineering and mathematics (STEM). A good many people, however, leave the supply line along the way for many good reasons (the leaks), and this loss is then felt in employment within STEM commerce and industry (Wang & Degol, 2017). Given the increasing technical demands of modern society, action is deemed necessary by government, universities and schools either to 'seal' the leaks or simply increase the initial input to make good the losses. A further concern is that those legions 'lost' to STEM from the pipe experience cultural, gender and class biases that render much eventual STEM employment non-inclusive, non-diverse and therefore become largely White, male and middle class: the pipe has quite selective leaks (Makarova et al., 2019).

Our challenge to this model comes in several forms: STEM is a vast arena, and there are many different destinations for both study and employment; there is no single channel for recognised achievement. Very few people will become prize-winning architects, chief

medical officers or 'prized' research scientists (Lunnemann et al., 2019); the end of the pipe is more often 'wide spray' than 'focussed jet'. While some people do enter early and leave early, others come to STEM later and enter 'mid-stream', as it were, through reconfiguring their lives and re-training in employment. That is, the pipeline 'leaks' both ways. Given there is no single destination (the end of the pipe), then, success in life is much more polymorphous and multi-dimensional: it comes in quite different shapes and sizes. Our recent works on STEM stories (Salehjee & Watts, 2020, 2022, 2023) have looked to celebrate some of the cultural, gender and class successes that south Asian women (in our case) experience in their lives, rather than linger on the negativity implicit in the metaphor. The purpose of this paper is to contribute to the existing research on critiques of the STEM pipeline metaphor. We present three STEM stories of returning to STEM later in life, and present a qualitative process that employs phenomenography, narrative inquiry, the construction of STEM stories, a montage of these stories and a detailed discussion of validation. This detailed representation of qualitative research will be of interest to other qualitative researchers seeking to replicate the processes of constructing stories and montage.

Our participants in this study are an unresearched group of the general public who have so-called leaked from the pipeline and are now returning to STEM through learning, training and education. This 'late-onset STEM' return is self-chosen by individuals in their adulthood (aged 35+) rather than enforced in their workplaces. However, the existing literature widely focuses on schoolchildren and young adults, for example, Banerjee and Graham (2023) present an important report criticising the STEM pipeline metaphor, highlighting the issues of STEM subject choices across students' life cycle, but then authors did not go beyond the life cycle of formal STEM education, that is, what actually happens after the people have leaked out from the pipeline, and whether (or not) their participants returned to STEM learning and practices later in life.

There is also a plethora of useful literature on science, technology, engineering, and mathematics, separately or collectively, as STEM identity development among children, youth and young adults within formal STEM educational or professional settings. For example, Simpson and Bouhafa (2020) have conducted a systematic review of literature on STEM identity, incorporating empirical studies published between 2000 and 2018. Although they found studies on identity development among employed adults and parents, these studies do not specifically address how STEM identity is shaped among adult participants with no formal STEM education. There are, though, limited and important studies, such as Simone (2025), that have investigated this late-onset STEM return, generally involving women returning to STEM after career breaks to their respective hardcore STEM careers, such as engineering, mathematics and science. However, in this paper, we are looking beyond the prescribed degree level STEM education and careers, we are not entirely focused on 'career breaks' of one gender, and their 'on the job training', rather we are focused on our participants' (women and men) substantial engagement with STEM learning and practices in their professional or personal lives (Skrentny & Lewis, 2022), such as primary school teaching, family-based environmental activities, DIY and quiz works, all of which are important roles for the prosperity of the country's scientific and technological sector (Kennedy & Odell, 2023; Rothwell, 2013; Smith & Watson, 2018).

This paper also emphasises the importance of lived experiences, narratives and stories, which are widely used in qualitative STEM education research, including identity research. For example, Ho et al. (2026) recently used written stories to explore students' development of STEM identities, sense of belonging with STEM, self-efficacy beliefs, and classroom climate. Another study by Jehangir et al. (2023) explores and showcases the STEM stories of underrepresented minority students attending predominantly white institutions. Moreover, seminal papers in science identity research by Carlone and Johnson (2007) and Brickhouse et al. (2000) have provided guidance for conducting small-scale qualitative studies that focus

on stories (as cases) from a few students. We also employ this small-scale, storied approach to qualitative data collection. Though in this paper, the treatment of discussing these approaches is different from the qualitative literature available in STEM education, as we detailed the processes in how we construct three individual stories and how and why of using the approach of montage to link the three quite different individual stories with our aim to bring juxtaposition, as a defining feature of montage, into new possibilities. Moreover, a discussion of autobioracy, entre-deux and five-step validity, which are used in this research, will provide a detailed account of our empirical research choices, justifications and motivations.

## STEM, STEM identity and STEM story

The concept of STEM is not uncontested (Calucci-Grey, 2023). Debates abound over the extent to which STEM is actually four discrete disciplines, each with its own boundaries and ethos, or a single interdisciplinary entity with common interests and shared resources. Can ground-breaking research and innovation, the James Webb space telescope, for example, actually take place *without* aspects of all four disciplines? At a more humble level, can a classroom project to measure air quality on school grounds bordering a main traffic route take place without invoking the science of particles, the technology of instrumentation, the enumeration of results and the engineering of traffic routes? One of our STEM stories picks up this project later in our discussion. That said, it is very commonly the case that schools, colleges and universities design timetables and teach these as quite separate and clearly distinguished subject areas that seldom cross disciplinary boundaries. This is coupled with an inherent and lingering class-based conceit in the United Kingdom and elsewhere that elevates 'pure' over applied subject areas, so that 'white collar' science and mathematics are preferred to 'blue collar' technology and engineering. However, the three stories we present in this paper do not explicitly fall into the science and mathematics white or technology and engineering blue-collar-labelled jobs. Similarly, our research does not distinguish STEM as four separate subjects, and instead, it uses STEM, the integrated whole (Banks & Barlex, 2020). Our research sample is drawn from a wide cross-section of occupations and vocations, from accountancy to animal welfare, from engineers to environmentalists, nursing to nanotechnology, and so forth. We are interested in our respondents' experiences of living and working in STEM. To some extent, this is true for all members of the public, in that science, technology, engineering and mathematics impact everyday lives in multiple ways. Whether people are concerned with the vagaries of a healthy diet, the invasiveness of a colonoscopy, the cost–benefits of an electric car, the implications of climate change, the workings of their smartphone or the problems of waste disposal, they are confronted with STEM issues on a daily basis (Watts, 2022). Some of our research respondents, though, have made more of a commitment, possibly a new career in STEM, and it is their lives that form the basis of our stories, STEM stories, here.

A range of identity frameworks in STEM-focused research, preceding science identity frameworks, has been developed over the decades to explore and promote the experiences of living and working in STEM for the purposes of addressing low uptake and retention among children and young adults in STEM education and to develop a workforce that can evolve and adapt to a rapidly advancing science- and technology-oriented economy and public life. These STEM 'identity development frameworks provide insight into "why and to what" extent individuals engage in STEM-related activities' (Dou & Cian, 2022, p. 458), and so exploring these insights can help and support individuals and communities to engage more with STEM activities and to build stronger identification with STEM (Syed et al., 2019) both in their formal and informal lives (Chiu, 2024; Dou et al., 2019; Perez et al., 2014; Stringer et al., 2020).

The why and what of STEM engagement are developmental as identity construction is developmental (Morton et al., 2019), so they are subjective and personalised as different people identify with STEM and so engage with STEM activities differently (Salehjee & Watts, 2020, 2022, 2023), and this personalised development of identity is authored by the individuals themselves through subjective and structural negotiations with society (Gee, 2000; Giddens, 1984); that is, the identification with STEM, then, depends on various intrinsic factors (including self-interests, self-efficacy beliefs, self-motivation, self-ability and self-identification with STEM) as well as the extensional factors (such as community-based cultural practices, formal education, family culture, societal norms and standards, local, regional and global issues, etc.; Shanahan, 2009). Hence, the study of STEM identity explores people's unique journeys encompassing their everyday STEM lives as experiences of engagement with STEM activities. This exploration presents a personalised negotiation between (and among) intrinsic and extrinsic factors associated with the 'in-flow' into STEM after an 'out-flow', expressed by our participants through personalised STEM stories. STEM stories are central to gathering our participants' unique and personalised STEM journeys. Our own educational studies have been sparked by the following research questions:

1. What are STEM stories? How are they constructed and shaped?
2. Is there such a thing as STEM identity? How do stories contribute to both the inner construction and outer manifestation of STEM-identity?
3. How do STEM stories and STEM-identity signal success and counter the increasingly moribund model of the leaky pipeline?

We have attempted to answer these questions previously through a range of publications and presentations (e.g., Salehjee & Watts, 2020, 2023; Watts, 2022). However, here we respond to these questions by presenting STEM stories that showcase the unique and reverse entry of three 'late-onset STEM' adherents, Carys, Philip and Mehr as 'late-onset STEMers', through our phenomenographic study, and then use research montage (not bricolage) to analyse and present our findings. The discussion of methodologies and methods is detailed in the next section.

## MATERIALS AND METHODS

### Phenomenography: STEM Lives and STEM stories

Our qualitative work on gathering and analysing STEM stories and exploring STEM identity development lies between phenomenology and ethnography in a mode referred to as phenomenography (Marton & Salio, 1984). Phenomenography (Marton & Salio, 1984) is well-established in education and adapts phenomenology's fundamental framework by capturing lived experiences at a subjective level (Beruin, 2022; Marton & Pang, 2013; Yates et al., 2012). Like ethnography, it focuses on learning about people's everyday lives belonging to a specific community (Schensul et al. 1999). We drew on the strengths of phenomenology and ethnographies' use of qualitative methods, such as interviewing a small sample of people to gather in-depth descriptions of individuals' everyday lived experiences, participants' interpretations and closeness with the participants, which remained distinct from our participants, that is, developing a hybrid space between first-person and other-person accounts. We slightly deviate from phenomenology, focusing more on variations in interpretation among our three 'late onset STEMers', and we slightly diverge from ethnography, as our study of communities is quite broad, encompassing people of different genders and from diverse ethnic, social-class, cultural, educational and professional backgrounds.

Our own brand of phenomenography uses narrative means to gather and present everyday lived experiences, STEM lives, of people as 'STEM (life) stories'. It is an interpretative approach aimed at bringing the reader closer to the phenomenon being studied (Bansal & Corley, 2011; Leitch et al., 2010). The variations in the interpretations of the phenomenon studied here are the 'why and what' of people's early leaking out of the STEM pipeline, late-onset return to STEM and their personalised development and evolution of STEM identity, through subjective and structural negotiations with society. Like narrative inquirers, we view stories, here STEM stories, as the principal mode of communication because '[s]tories describe human knowledge regarding experience and action' (McIssac, 2008, p. 323). We therefore give careful attention to our participants' biographical details, previous experiences and major life events (Salehjee & Watts, 2020). We bring evolving stories of how individuals develop STEM identities (*without* a considerable formal education in STEM) as all of our 'selves … always in the making' (Greene, 1993, p. 213).

Like several narrative research studies, we draw on the lived experience literature. For example, drawing on Abbott and Wilson's (2015) study, we take STEM lives and STEM stories to be

- *Reflective of action and agency*. It contains an 'authoritative tension' that implies intersectional power relations associated with forms of knowledge and knowing, and between social structures and individual agency to act. The development of STEM identity research, as mentioned above, forms the basis of exploring and presenting the tensions and dilemmas that they have come across, which made them negotiate with the social structures (extrinsic factors), for example, STEM is not for women (Mehr), and how they have agentically (intrinsic factors) acted upon them, indulging in informal STEM learning experiences and activities (Mehr & Philip).
- *Personally felt, vast and diverse*. Lived experience is essentially subjective, personal and arises from past, present-immediate and even evolving and upcoming experiences. So, we are interested in capturing and showcasing STEM stories that comprise personalised, evolving experiences shaping how people view, act and react to different situations and occasions in their everyday STEM lives. This is most certainly reflected in our collection and presentation of all the STEM stories.
- *Acting principally at a subconscious level*. Lived experience is emotive and has its own logic. It often comprises facts, fiction, images, ideas, imaginations, preconceptions, aphorisms, normative values, stereotypes and much more. The emotive aspect of experiences is mostly viewed to be the reason for re-entering into STEM learning, for example, the death of a puppy due to plastic suffocation, followed by self-taught learning about plastic and plastic pollution and spending holidays in beach cleaning activities as a family (Philip).
- *Collective as well as personal*. There is such a thing as shared experience. A sense of community, a collective spirit, allows for debate and challenge within ourselves and engagement, debate and challenge with others. In all the STEM stories, the aspect of immediate community (family and colleagues) was evident; for example, returning to STEM learning to accommodate the employer's needs (Carys).
- *Culture and context-bound*. Lived experiences are shaped by personal and collective positioning in society, the norms and values associated with our cultures and the scale of interactive events that affect us. The STEM stories we present demonstrate everyday events that shaped their identification with STEM and how they intersected with their everyday culture. For example, Carys, Philip and Mehr maintain a pro-STEM culture at home and/or work.
- *Beyond statistics and numbers*. Exploring and representing individual and collective experiences opens up 'realities' of the life world that are not easily amenable to quantification. This is certainly the case for our three participants, as despite their leaving STEM after

age 16, their experiences, reasons for re-entering STEM and the context in which STEM identity develops differ from one another.

We see lived STEM experiences, that is, STEM lives, as a process of broadly tacit personal and social explanatory systems that continue and evolve throughout life. Over time, people look to make sense of where they are, what they are doing, and what is happening to them. The importance of explicating and collecting personal STEM stories lies in the insights they provide—analysis that goes well beyond forensically or academically presented knowledge.

## Autobioracy and entre-deux

### Autobioracy

We derive autobioracy from auto (self), bios (life) and oracy (to speak). Coined first by Andrew Wilkinson in the 1960s (e.g. 1965, 1968), oracy was defined as the fluent, confident and correct use of the standard spoken form of one's native language (MacLure et al., 1988). Our work here is to gather life stories from our participants (the narrators) in an oral form. In doing so, we present the dominant meanings or narratives to showcase the origin and evolution of each participant's stories as auto-bio-narratives. Thurner (2021) used the term 'embodied auto-bio-narrative' to 'show and reflect our specific aspects of current dancing (life) stories'. How a body can narrate life' (p. 214). Thurner is interested in life stories associated with contemporary dance and its historical evolution, while we aim to gather STEM (life) stories comprising present, past, and future descriptions, explanations and reflections on their everyday experiences with STEM. For us, 'auto-bio-narrative' has a clumsy feel and so prefer to use autobioracy as participants' personal narratives revealing their overarching meaning, their stories as they shape and re-shape over time. To this extent, we see our participants as 'transformative intellectuals' (Giroux, 1988) as they craft and re-craft their STEM stories of engagement, self-dispositions and actions while simultaneously exploring the meaning of STEM life in the greater swell of things.

Ours is an 'opportunistic snowball' sample, recruiting participants (i) who are UK citizens, (ii) who left STEM formal education at 16 and continued with non-STEM education and professions post-16 and (iii) have re-engaged with STEM in adulthood (age 35+), in their personal and/or professional lives, well beyond school age. We call our participants 'late-onset STEMers' (Table 1).

Our usual research approach (Salehjee & Watts, 2023; Watts, 2022) is through word-of-mouth recommendations, a request to meet and talk about 'STEM lives' over coffee and biscuits, or the internet. Carys, Philip and Mehr's (pseudo-anonymised names) autobioracies were collected individually, and before these hour-long interviews, we had 20–30 min of conversations with each about their involvement with STEM, their educational backgrounds and current professional activities. The hour-long interviews, comprised of open-ended questions to gather STEM lives, including: (i) their current and past experiences of engagement with STEM activities, (ii) their reasons for re-engaging with STEM activities in their everyday lives (professional and/or personal lives) and (iii) opportunities and barriers associated with STEM engagement.

### An 'entre-deux' approach

Life histories and personal narratives do not write themselves (Tomsic & Zbaracki, 2022). The researchers, as recorders and editors, have a heavy hand in their production.

**TABLE 1** Our participants.

| Late-onset STEMers | Education | Employment |
|---|---|---|
| Carys | Philosophy and Education | Primary school teacher |
| Philip | Business studies | Supermarket chain manager |
| Mehr | Business and economics | Banker and primary school teacher assistant |

Nasheeda et al. (2019) describe a step-by-step process for transforming transcripts from multiple qualitative methods into stories, acknowledging that there is no specific way to form meaningful stories or narratives from transcripts. In our work, we use our researchers' third-person accounts to contextualise and identify details of the events under discussion. We then classify these events to make sense and meaning of single and associated events. That is, we re-tell the stories to form edited-for-meaning narratives. Within these, we include first-person voices and actions, as well as direct quotes from the transcripts, to convey participants' self-perceptions of their STEM experience. Papadopoulou and Sidorenko (2022) rightly ask the question, 'Who's voice is it anyway?' Our response is to see both first-person and 'our-person' accounts as equally important and complementary. Therefore, this paper adopts an 'entre-deux' approach, that is, an in-between positioning: we portray the exact events participants offer us and, from these events, we present stories we believe bring meaning to the larger narrative. In our re-telling, we have necessarily trimmed and edited, 'grammaticised' and sometimes abridged our respondents' words. For example, quoted speech is edited, and 'messy' spoken language is clarified to enable greater readability. As authors, we do have a voice, not least in our choice of questions, our 'take' on what is said, our explication of links to the core agenda and our selection of quotes for presentation to readers. As Brodkey (1987) points out, stories do not explain themselves. Therefore, an analytic, interpretive ethnography inevitably involves a retelling of the story through the explainer's eyes. That is, we have 'storied' their stories, interpreted what we think our participants are saying and presented them as STEM stories. We ourselves are neither inside the story nor outside of it; hence, the entre-deux.

## Positionality

There is no denying that power-positionality remains at play. We are both seen—appropriately or otherwise—as expert scientists and sources of authoritative answers and explanations. We are the researchers with an audio recorder in hand; we are evaluators, validators and eventual publishers of participants' responses, albeit through permission-granted and ethically approved institutional procedures. We have included participants' biographical details, the cities in which they live, and institutions at which they have studied, only if they want these used in their accounts. We are both university academics, one of south Asian origin and female, the other White, grey-haired and male. Despite any jovial, affable modesty and self-deprecation, we carry all this into each interview situation we generate. There is no doubt, therefore, that the responses we receive and the conceptual structures we read from these are heavily filtered as a function of both the context, conduct and character behind our work in STEM education research. In addition, we see ourselves as informal STEM devotees, as we strongly believe that STEM influences our personal lives significantly. Others, our colleagues, students, family and friends, view us as carriers of STEM interests, knowledge and skills. These teaching and research experiences, enthusiasm and affection for STEM will influence our interpretations of the participants' stories; however, along with our strong focus on STEM identity as subjective and evolving stories, self-constructed by

the individuals, simultaneously, these individuals gave us their permission to explore and present their STEM lives.

## Montage not bricolage

We need here to note our resistance to the terms—*bricolage* and to *bricoleurs*. Over time, qualitative researchers have appropriated Levi-Strauss's original notion of bricolage, working with 'structuralist inquiry' as a metaphor that not only invokes piecing together materials but also revealing the 'meaning-making processes' involved. Such processes are influenced by pre-conceived, existing and (un)seen structures and existing cultural norms, values and practices (Santiago Sanchez et al., 2025, p. 802). Odegard (2021), for example, has used bricolage in an early childhood research project because the researcher, as bricoleur,

> explores and builds different knowledge-production pathways, allowing experimentation with a wide range of methods and theoretical perspectives…. various data can be read by bricolaging it together, resulting in several narratives that may disrupt and challenge dominant discourses and present alternative perspectives in early childhood pedagogy
>
> (p. 20).

While the bricolage metaphor does draw attention to researchers' agency, creativity and craft in the process of designing, conducting, and presenting research outcomes (Klag & Langley, 2013), it also carries an unhappy sense of 'cobbling things together' (Duymedjian & Rüling, 2010, p. 141). Such a colloquialism implies a process that is 'make-do', rough, slipshod and somewhat careless.

Our preferences are for discussions of assemblage and montage. Jackson and Mazzei (2012) describe assemblage as 'the process of making and unmaking (…) of arranging, organising, fitting together' (p. 747). Lucas (2012) proposes that assemblages are 'collectives or systems of usually familiar entities (which include humans, pots, arrowheads, etc.) that cohere in stronger or weaker ways and for longer or shorter durations […] highly unstable or fluid, continually churning up matter and functions in a way likely to create change' (p. 375).

We stress that assemblages are not merely artificially cobbled-together heterogeneous bits and pieces. Rather, they are dynamic gatherings of corresponding things entangled through human practice. For example, our participant Carys' decision to pursue a teacher training course and work as a primary school teacher, even after gaining a philosophy qualification and working at a travel company, is entangled with her family's professional choices. Assemblage, inspired by its specific use by Deleuze and Guattari (1987), is thus a resource to preserve a mix of the aesthetic and the structural. As with most creative processes, assemblage can involve messy trial and error. It is an emergent construction that evolves as the research process unfolds (Charmaz, 2014) to form a composition in which the parts present different perspectives (Denzin & Lincoln, 2000). This aspect of different perspectives, as evolving perspectives, is important in our work on STEM identity development, for example, Philip's overnight change in his perspective from not (willingly) engaging with STEM activities in his everyday life, to a perspective that he needs to learn and be engaged with the learning of plastic pollution.

We see montage as the active design of a coherent study customised to answer specific research questions. By this we mean a composite picture made by combining several separate pictures at hand carefully, selectively and reflexively for clearly stated purposes: it enables us to assemble, frame and synthesise diverse multi-modal data for analysis and

interpretation. This helps create an 'effective arrangement' (Duymedjian & Rüling, 2010), contributing to the overall trustworthiness of the research. In exploring the montage, we jostle incompatibility, juxtaposition and equivalence with the requirements for validity. Montage brings different 'bits' of data into play to reconstruct and link elements of our participants' stories and incorporate other perspectives to explore emergent themes. Linking diverse bits of data is 'a representational practice in which sections are arranged into sequences to condense space, time and information' (Mann & Warr, 2017, p. 549). The montage, therefore, has an organising function that opens up new possibilities and allows us to think differently about the three stories we showcase here.

In this article, a montage organises a way of thinking differently about STEM stories by rearranging instances of conversation and context. The assembled montage is rearranged and added to as it takes shape. We consider our material and the multiple ways of organising it to be an assemblage of chosen elements and aspects, and necessarily, by making a choice from within the data, we leave behind other parts that 'escape' the montage (MacLure, 2013).

The key steps we took to link the different and diverse 'bits' of interview data, assembling and reassembling, forming STEM stories and exploring emergent overall themes for discussion, include

1. Identifying different events and associated contexts and circumstances for the three participants separately. These identified events involve participants' past and present lives, expressing the reasons for their choices to leave and then re-enter STEM learning and practices. Importantly, we were interested in exploring Carys, Philip and Mehr's diverse perspectives on their return to STEM. For example, events and associated contexts and circumstances relating to individualised perspectives on their families and people around them, personal and professional needs, society and the environment and barriers and opportunities to engage with STEM in older age.
2. Assembling the identified sequence of events (step 1) of each participant by looking at their oral accounts from multiple perspectives, revealing the successes employing a non-linear trajectory towards STEM engagement and the development of STEM identity. For example, changes and successes imnclude Carys's self-realisation and appreciation of everyday STEM at work and home; Philip's realisation that their generation needs to take responsibility for the detrimental impact of valuing plastics on the environment, and Mehr not viewing herself as an STEM person in school, but later in life leading STEM projects as a teaching assistant.
3. Reassembling the assembled sequence of events (gained in step 2) into condensed STEM stories of each participant, employing logical sequencing of the narratives. Different events are then synthesised (linked) to provide a narrative layout. For example, within the narrative of identity development, Carys's perspectives on her identity evolve from a music and history enthusiast to a primary teacher, to a STEM specialist teacher, and to a STEM enthusiast. This journey, which Carys did not tell us in this order, but we reassembled here to showcase STEM success in a logical fashion.
4. Construct a montage of individual STEM stories by comparing and contrasting these STEM stories, arranging and rearranging the different bits to make sense of the phenomenon being studied and producing emergent themes for discussion. In the discussion section of this paper, we have identified and discussed seven themes obtained from the three STEM stories. These are
   a. A montage of STEM stories: Convergences and divergences.
   b. Disconnection and reconnection with STEM engagement and identity.
   c. Informal multimodal learning vs. structured formal programmes.
   d. Family and social circumstances—stimulus, support or stricture?

e. What are the signals of emotion in the telling?
f. Pictures of non-linear success.
g. Timelines and the importance—or not—of mid-stream entry.

## Autobioracy montage validation

Validation is an age-old concern for qualitative researchers. Back in 1986, Lincoln and Guba proposed the term authenticity, whereas Polkinghorne (1988) argued that validity in narrative analysis should be seen in terms of 'verisimilitude'—'results that have the appearance of truth or reality… [that are] well-grounded and supportable' (p. 176). More recently, Schwandt et al. (2007) have argued that authenticity enables questions to be asked about how interpretations are made and how this process has evolved. In our terms, when one weighs the evidence, just how persuasive is the overall picture? In previous work, we have described our position as 'protecting against *invalidity*' rather than necessarily promoting validity in itself. There is a difference: we see no virtue in describing our work as valid in any absolute sense ('Is this study valid, yes or no?'). Like beauty, validity lies in the eye of the beholder, so that some educators of a quantitative disposition, driven by correlational statistics, for example, will rarely see validity in more subjective qualitative research. Our researcher role, then, is to minimise faultlines and maximise quality.

We see this process of 'invalidity proofing' in five forms: contextual validity, theoretical validity, respondent validity, criterion validity and consequential validity (Pedrosa-de-Jesus et al., 2013). None of these takes precedence over the others, and the combination morphs with the kind of study under consideration. In our own narrative research, for example, setting the context is important—do others in the trade see this as important (valid) work to be doing? Can a compendium of stories make inroads into some of the pressing issues that face us? Does the collection matter? In answering these questions, we researched the gaps in the literature of, say, the STEM pipeline and the historical trends of women leaving the pipeline and policies to increase the underrepresented population back in the pipeline, but then no explicit research actually discusses the what and how of STEM engagement for a group of people who have long left STEM education but are returning with self-interest and motivation. Therefore, gathering STEM stories from this group of people could provide us with insights into their successful re-entry into STEM, privileges and barriers faced in their return, and to further the critique of the STEM pipeline concept and so the collection of these STEM matters, as the majority of our population who are reported to have leaked out of STEM and viewed never to return (Banerjee & Graham, 2023), but the three cases we discussed in this paper have shown a return into STEM-focused learning and working. Theoretical validity demands that we demonstrate theoretical 'congruence', that our theoretical lens is compatible with and sensitive to the empirical decisions we make and the outcomes we generate. As mentioned in previous sections, our empirical work in this paper showcases the 'in-flow' of people back into STEM learning and practice who are stereotypically viewed as unable or unwilling to enter the pipeline. So, the STEM identity framework can showcase the why and how of inflow into STEM despite being viewed as never returning to the pipeline. Respondent validity is central to the ways we work. As mentioned in the previous section, we recognise our active influence within an entre-deux position. We have checked back with each participant and, when asked, have revised our edited versions of their transcripts, including most, but not all, of the events they shared, our other person's perspective (i.e., our commentary on the stories), and the formation of overarching narratives aligned with their first-person perspectives. Criterion validity entails marking the outcomes of the research in light of the contextual backdrop, and how they can be seen against previous studies in the field?

How well do they stand up to scrutiny on a wider stage? Previous studies in the field, for example, on STEM workforce shortages and STEM identity, serve as the contextual background, which we have read and reread, written pieces that are reviewed by academic peers, critiqued and edited by us, and published over many years. In addition, we have critiqued our own work in areas such as the use of 'science' rather than 'STEM identity' and the lack of discussion of the 'in-flow' of people back into the STEM pipeline. Finally, consequential validity tests the 'so what' of the research. It is possible, we suggest, for research to pass all the other tests and still be seen as little value, as being largely inconsequential. The so-what test of the research here is to explore and showcase the unspoken, unrecognised and unappreciated STEM lives of people like Carys, Philip and Mehr, re-entering STEM and developing an STEM identity in their own unique ways and on their own terms.

In combination, these five validation processes provide a 'shielding picture' that, while certainly not guaranteeing or securing validity, goes some way to rebuff invalidity. The qualitative researcher working with narrative accounts has the daunting task of giving rich contextual descriptions of the settings and the characters involved, providing convincing portrayals and quotes, working carefully through the oral and associated evidence to give compelling interpretations and analysis and in positioning themselves reflexively with the research. In their contemporary work, Small and Calarco (2022) argue for forms of qualitative literacy and focus on quality rather than validity. They describe five forms of quality in narrative research, which include, for example, issues of heterogeneity and palpability. They point out that one key difficulty with the outcomes of narrative research is that every story is different, so, as here, Carys, Philip and Mehr's stories are different and personalised. Therefore, keeping the individual STEM stories intact and next providing a montage of them opens up new possibilities and allows us to discuss them in a new light. Moreover, it is exactly those differences that we value and seek—we need, as Small and Calarco suggest, to 'lean into' the differences and not mask them. Yes, we can value homogeneity, of sameness or similarity, where that makes a point, but this is always sharpened by heterogeneity, the divergencies, the differences, the exceptions that make a more shaded or nuanced point driven by their particularities and peculiarities. Too much similarity or homogeneity, they argue, is suspicious—for example, either the interview questions were too bland, or the researcher failed to probe sufficiently. Exceptional elements, they say, make stories more palpable and believable, as is evident in ours.

## STEM STORIES OF 'LATE-ONSET STEMERS': CARYS, PHILIP AND MEHR

### Carys

Carys is a primary school teacher in a London 5–11 age-range school. Born and raised in Wales, she is a native Welsh speaker who was securely arts-based throughout her schooling and studied philosophy at Aberystwyth University. Both parents and her sister are teachers, and she laughs when she says teaching is in the blood; there has been little hope of her ever escaping the family business. She spent 3 years as a travel company representative before conceding defeat and training at a west London university to be a primary teacher. She has been teaching at her current inner-city school for 5 years. This school was in a dilemma where Carys had to act on it by learning science in her 30s, with the realisation of not having 'done any science' after the age of 16:

> We are short-staffed, I guess, like loads of schools around here, and we had no one who specialised in science. The headteacher started pleading with me, wore me down eventually (!), so I took a subject specialist course, afternoons and evenings, because I had never done any science in my life! Well, only to sixteen, and I never paid a smidge of attention back then, too busy with music and history. But it was a revelation – I really enjoyed it. It was pitched right smack at my level of stupidity! It was a small group, we were all inexperienced, and I could ask all the idiot questions I liked – and even get answers, it was brilliant!

Through her engagement with the science specialist course, Carys experienced a gradual shift in self-perception, moving from viewing herself as lacking a science background to recognising her capability as a science learner. This developing sense of competence emerged alongside the challenges she faced within the taught programme. She recalls a particular issue in her taught course:

> I remember this one session about organisms that lay eggs. Well, I grew up in a farming community, didn't I? And so, eggs were, well, eggs, you know, bacon and eggs, dippy eggs, omelettes, that sort of thing. Hen's eggs, duck's eggs, free range, whatever. I had never thought much about the sorts of animals and insects that lay eggs – snakes, turtles, and alligators lay eggs! – exactly what eggs are, about a woman's ovary and eggs, and so on. And, of course, the role of the cockerel on the farm! It was so fascinating, so enjoyable, I got hooked.

The above evolving STEM experiences later sparked the development of STEM identity. In this evolution, the aspects of emotion and logic are evident. For example, the fear of doing science after a long time, but then the feelings of enjoyment and being hooked with the new knowledge burst the bubble of her preconceived ideology that STEM is an alien territory. This personal acknowledgement of her STEM abilities and enjoyment extended to her engagement at the broader school community. As over the next few years, Carys became the 'go-to' person for science at the school. She developed the science provision, lesson plans for other teachers, the outdoor nature areas, teaching materials and library resources. She attended numerous professional development courses in neighbouring institutions and even attended a science education conference in a nearby city, accompanied by her sister. She did admit, grinning, that the social life at the conference was every bit as engaging as the science. We asked her about her relationship with STEM, and her personal transformation towards being now 'pro-STEM':

> I knew you were going to ask me this, so I thought about it. Two things, I guess. First, it's a bit like learning any language, you know, French. You are never going to pass as a native French speaker, a Parisian, and so you simply do the best you can. You can work on vocabulary and pronunciation, read papers and watch films and stuff, but it's always going to be a work in progress; you'll never get all their sophistication and nuance. Same with science, I'm working at it, but I'm only at step one. We do have a maths specialist and a technology guy at school, and they cover those parts of the curriculum, though we do talk a lot about how to integrate them as STEM. We have been devising these great projects, and now we have a STEM week every year. We invite guest speakers, university people, and set the kids great problems to solve. It's really good! We are not ditching the rest of the curriculum, just joining it all together.

She described one particular project showcasing her extended intersection with her everyday professional culture:

> The school is on a major through-route and the Head and school governors have been campaigning for years to have traffic-calming humps and slow-down signs, lollipop people and everything. We decided to go the air-quality way, and the school bought three cheap air-quality monitors. We set up class teams to take readings morning, noon and night. The children understood that the actual placing of the monitors was important, the timing, the need to have three devices to check on each other, the way to record the readings, average them, and so on. We got important results, but we soon realised that the local council wouldn't listen to our work because the monitors only did carbon dioxide levels and not much else. So, we had to get better equipment. The kids sourced the best affordable one, but it was quite expensive, so we could only buy one. That compromised the experiment, but they decided since it was more expensive and did all kinds of particles in the air, it would be more accurate, and so we could work with just that.

She paused, then

> Second, I'm not afraid of it anymore. I can say quite cheerfully that I don't understand and know that I am in good company – there's lots of people who don't understand! And that includes some scientists! We tell the kids, it's OK not to know; the trick is to go find out. So now I can watch technical programmes on TV without switching channels, in fact I LIKE watching David Attenborough, discovery and techie-TV. It's a whole new world and there's so much to learn.

The above quotation reiterates the evolution of emotions from being fearful to not being afraid, and negotiation of self (intrinsic) and others (extrinsic) as the understanding of a community that does not understand science, boosting self-confidence that started with attending the subject specialist science courses and her immersion in STEM, creating a pro-STEM professional culture for herself and the children she teaches. Hence, re-entering STEM at the headteacher's pleading leads to gradual progression in STEM engagement, which in turn leads to continuous development of her STEM identity.

## Philip

A degree in Business Studies, considerable experience in management with a large supermarket chain, Philip decided to branch out and take a senior position with a relatively small office cleaning company. The company was based close to home, and he felt that, while the role was demanding, it did allow for a greater quality of life with his teenage family. He felt he was mathematically and financially astute, as befitted his work within the company, but cheerfully admitted to having left science and technology way behind in secondary school and had very little contact with anything much related to engineering. This changed overnight when his daughter's puppy suffocated and died while chewing a plastic drink bottle, and Amy burst into tearful outrage at the immorality of plastic pollution. This incident sparked a family quest, fuelled by television news and popular documentaries, by online searches and social media, to understand the nature of plastics, why it was such a universal material, the range of uses, the processes of recycling and disposal.

> I felt I was at the centre of a storm! Jane [wife] and I were seen as the evildoers because 'people like us' were the generation that invented and venerated plastics and, essentially, had murdered Amy's [daughter] puppy. I took the view we had to learn *why* plastics were so *everywhere* in everyday life and then think about what to do about it.

This approach had worked tolerably well, he said, until he happened to mention at home the wide use of plastic containers within his cleaning company.

> They [plastics] are perfect for all of the everyday fluids we use—lightweight, easily portable, non-reactive, semi-transparent so you can see liquid levels inside, they're stackable, safe… and so on. There are no easy solutions at work—despite Amy's very loud remonstrations—and I managed to turn her attention to the mass use of plastics in the food industry—not least drinks bottles, of course. We did several family projects about food transportation and packaging, and I must say, her schoolteachers were very understanding. We, all of us, went from zero to a zillion in our knowledge about polymers, plastics and pollution; we were all experts very quickly.

The family quest culminated in a week working at an organised spring holiday 'beach clean' along the Pembrokeshire coastline in Wales. Despite cold and rainy weather, they worked alongside other beach-clean enthusiasts, scoured beaches, learned a vast amount about sorting and grading plastic waste, the volumes of such materials produced around the world and the dangers to wildlife and the environment. Philip said,

> We now have our own Greta Thunberg in the family. None of us had previously been particularly 'sciencey' or 'techie', but we are now! And with Amy, we're certainly on a sharp learning curve.

Philip's story exhibits a transformation in mindset, from willingly leaving STEM education to willingly re-entering STEM learning and practice later in life. This transformation in mindset began with the negotiation of an intrinsically emotionally charged dilemma associated with the extrinsic dilemma of plastic pollution in the world, leading to an acknowledgement and appreciation of everyday STEM, a celebration of STEM in their lives and, eventually, the development of Philips' STEM identity.

## Mehr

Our third mid-point 'STEMer', Mehr, self-identifies as a Scottish Pakistani woman. She is a proud mother of a scientist daughter and an engineer son. Her engagement with STEM was evident from a very young age. However, all the stereotypical images of STEM education for boys were apparent during her school life, and she said she lacked female role models to challenge this. Nevertheless, she continued her own informal STEM learning through science quizzes, puzzles and DIY home activities. Her family's culture fostered her enthusiasm for building her 'problem-solving' skills and never hindered her passion for STEM learning, especially in mathematics and engineering. Despite this supportive home environment and her interest, she discontinued her formal STEM education at 16 and entered the banking sector. Why? Because she saw that banking and finance studies involved problem-solving and mathematical operations. During her financial career, STEM remained part of her home culture, STEM-based conversations and activities so that, as a family, they:

> watched science-related programmes on TV, [such as] quizzes, and things like that. My dad was a keen quizzer… Obviously, as a family, we were involved in various DIY activities, assembling shelves, tables, and cupboards ourselves and various [home-based] engineering work [amongst us]… growing up, my mom especially loved decorating the house, painting, wallpapering, and doing everything herself.

After a few years, Mehr left her bank job and devoted time to raise children. She gave them a similar pro-STEM home culture to the one she experienced. In addition to quizzes and DIY, Mehr said

> The Royal Institute's Christmas lectures were always fascinating, and I watched them growing up… and then, when my kids were younger, I used to make them watch too. Still, we watch and discuss topics like anti-vaccine campaigns, etc. This year it was on forensic science – fascinating stuff.

While Mehr's children were at school, she began working as a support staff member in an after-school care centre. In this centre, Mehr became famous for introducing puzzles and jigsaws in the classroom, aiming, 'to introduce lots of different problem-solving activities and not just, you know, the typical stuff'. After her successful experience with young children, Mehr began working as a member of the teaching support staff at a local primary school. Although her job description did not explicitly include designing/conducting STEM activities, still, like her pro-STEM home culture, she actively participates in embedding STEM learning to enthuse young children's STEM interest, so she introduced,

> a lot of action in maths [including] a lot of problem-solving activities [in the classroom], and also trying not just to give them the answer but working out how the children get to the answer… We've got jigsaws… Lego as well… Lots of digital learning… We introduce science experiments like designing volcanoes… trying to get the children to make a bridge from one end of the desk to the other. So really, just giving them a lot of resources. And then they've got to figure it out. How can they make a volcano, what chemical reactions make a volcano erupt, and what makes a durable bridge? And you help them as they solve these problems and give them ideas, but [you are] not obviously doing it for them. But just let them get in their minds working.

Therefore, even without an STEM degree, Mehr created an STEM culture at home, helping her own children pursue STEM education and careers and supporting primary-aged children in the workplace. Still today, Monday nights are special as they are Quiz nights with quiz programmes, including *Pointless* and *Mastermind* as her favourite, *Only Connect*, is on Tuesdays. Mehr never felt that informal STEM was not part of her, as she enthusiastically mentioned:

> I just think sometimes science and maths just always stayed with me [as] I've always liked anything I do that leads to finding a solution to a problem, and STEM knowledge and skills give the tools to find answers or make things better in life. Such to control my blood pressure, I'm trying to exercise more. So, I go out for walks. Do yoga with the neighbour; I want to get back on my bike this summer because I need to get my heart stronger and blood pressure down, etc.

Mehr's STEM story portrays the various ways, mainly informal, in which she remained engaged with STEM on/ off, despite leaving STEM at an early age. Mehr leaving STEM

formal education was, in a way, extrinsically enforced by the stereotypical societal pressure she felt intrinsically. She then, in her late 40s, found her STEM engagement grounds through working as a teacher assistant.

## DISCUSSION

In this section, we return to our three research questions (RQ1, RQ2 and RQ3) to present a montage of three STEM stories using seven themes, highlighting convergences and divergences among the STEM stories, STEM identity development and counter the moribund STEM leaky pipeline model.

### RQ1: What are STEM stories? How are they constructed and shaped?

In the previous sections, we discussed the construction of STEM stories; here, we discuss how they support the construction of a montage of these stories.

#### A montage of STEM stories: Convergences and divergences

Mann and Warr (2017) discuss the benefits of using the montage technique to assemble distinct, unrelated and different forms of data, including 'drawings, song lyrics, photos, texts and observation' (p. 551) from the same (or different) individuals to establish

> opposing standpoints and perspectives can be juxtaposed so that meaning and interpretation is synthesised through the ways in which they are arranged to form sequences and layers of understanding
>
> (p. 549).

In this study, we first constructed STEM stories of Carys, Philp and Mehr, presented in the previous section, next similar to filmmaking, where montage is used to give scenes a narrative structure through linkage and juxtaposition, so we viewed scenes (issues) from multiple perspectives. Here we have two teachers, one business manager; two women, one man; one individual, two family accounts; people of different ages, cultures and heritages: as much as our stories converge around igniting STEM-identities, they also diverge considerably in context and character. Second, constructing a montage by putting these stories side by side gives the impression of widespread occurrence, showcasing the late-onset influx into STEM learning and practice.

The dominant picture in STEM education is the 'pipeline' loss of talent and expertise from STEM, based on gender, class, culture, and/or heritage. However, while the big picture from a mass of data might provide a unified account of 'what is', there are significant differences in our STEM stories of mid-life STEMers, countering the leakage concept associated with the STEM pipeline metaphor. We use their stories to animate the picture in a way that allows us to zoom in on various features, with a focus on personalised STEM stories in detail or by zooming out by comparing the three STEM stories, to see those features in the context of re-engaging with STEM at workplaces and home. While we picture a series of similarities and differences, we also acknowledge the inherent complexity in our patterns of contrasts. As, these are just three instances of an extensive and prevalent situation within a broader population. That picture is, of course, both accurate and yet not; there is little research to date that specifically explores adults' (re)emergence into STEM activity engagement and identity.

That said, there is an accumulating body of literature, for example, charting growing environmentalism, spring bud-watching, garden bird counting, wildlife conservation, field-study attendance and so on; some—perhaps much—of this would embrace late-onset STEMers. There is little in the literature, though, to indicate who, how many and why. Our picture, then, does hint at pervasive commonality but, more importantly for us, highlights our premise that many people occupy an STEM life in one form or another, and that this can come alive at certain points in life.

## RQ2: Is there such a thing as STEM-identity? How do stories contribute to both the inner construction and outer manifestation of STEM-identity?

A montage of our three STEM stories highlights STEM identity, presence, and development among late-onset STEMers:

### Disconnection and reconnection with STEM engagement and identity

Why do people disconnect early from STEM, only then to reconnect in later life? At the start of the paper, we touched on just some of the many (many) reasons offered in research accounts within both science and mathematics education: boredom, tedium, frustration and/or irrelevance, the deadening of creativity and curiosity within school lessons. For some, science, mathematics and technology are seen as arcane, obscure, unintelligible, not worth the 'heavy mental lifting' seen to be involved in their study. For others, it is a matter of personal identity—that is simply not how they see themselves, and meanwhile, there are too many other, more interesting, things to be doing and ways to be in our stories. Then we also touched on the why and what of engaging in STEM activities, as STEM identity development evolves over time and is personalised; it is not clear that Mehr ever really did disconnect; maybe she merely paused as she raised a family. For Carys, she was 'nudged' by professional pressure to engage; there was no one else in the school to do 'it' (STEM), whereas it was a critical incident, the death of the family pet, that galvanised Philip's activities. Here, the stories overlap in the montage. While parts are different, our STEM stories speak of commonplace occurrences; these are not extraordinary situations. The overlays speak to the everydayness of these people's lived experience, STEM lives, of reconnecting to STEM, which develops their identification with STEM.

### Informal multimodal learning vs. structured formal programmes

There are threads of informal multimodal learning and of leaving formal STEM education that interlace among the STEM stories. All three would have studied STEM—certainly science and mathematics—at school, but this seems long forgotten. Mehr and Philip are essentially self-taught, informally STEM-educated. Carys, too, to a large extent, although she has also taken advantage of formal university-based programmes in teacher professional development. It was, in fact, one such course that lit her STEM fire. All three make extensive use of multimodal learning—TV programmes, casual conversations, internet searches, YouTube videos, newspaper articles, discussions with experts, quizzes, hands-on construction and much more. Falk et al. (2016) call this 'free-choice learning', although their work refers rather more to visiting museums, galleries, botanical gardens, aquaria, makerspaces, planetariums, city farms, etc., than to the more at-home learning of

our three storytellers. The relationship with informal multimodal STEM learning experiences is distinct across the three STEM stories, but these experiences have brought them to STEM to an extent that our three participants continued their learning in STEM, leading to STEM identity development, in which they view themselves as STEM entrants. While all three of our participants seem to be somewhat tugged along by other people in their lives (family members, school colleagues), the three nevertheless illustrate a considerable degree of self-determination in their learning. Here, the montage has stitching or lettering across each STEM story to connect points of comparison.

### Family and social circumstances—Stimulus, support or stricture?

Here again, there are comparisons and contrasts in the stories being told. One (Carys) makes little mention of her 'teacher-oriented family', and the focus of her narrative sits within her professional life. That is also true, in part, for Philip, who describes the uses of plastics in his working environment. Both Mehr and Philip, though, have a strong sense of family in their stories—as positive stimuli to engagement with STEM in both cases. All three describe their active commitment in working with STEM ideas, although it is Carys and Philip who actually take this outside of their immediate 'comfort zones' to monitor air pollution three times a day or clean a beach in cold, wet conditions. The effort to go against the norm, pre-existing assumptions and perceptions of self-ability and interest exemplifies STEM identity formation, in which participants negotiate with their pre-held agentic needs with the immediate environment. Much of the literature relating to 'barriers to STEM' cites family resistance to girls' involvement, families of low socio-economic status, or families with low expectations (e.g., Archer et al., 2020). It is clearly the case that, whether or not such social barriers existed for them in the past, our three stories do demonstrate 'aspirant middle class' values.

## RQ3: How do STEM stories and STEM-identity signal success and counter the increasingly moribund model of the leaky pipeline?

A montage of three STEM stories signals STEM identity development and, in turn, a successful influx of our participants, countering the leaky pipeline concept in three principal ways: evolving emotions, non-linear STEM successes and no age or stage restriction.

### What are the signals of emotion in the telling?

It is not uncommon for young people to say they *hate* science (Charlafti, 2001), sometimes meaning a mere lack of enthusiasm, sometimes real loathing. Hate, distaste and animosity are some of the reasons for dropping the study of science or other STEM subjects in schools. Past work has explored affective dimensions of school science (e.g., Alsop, 2023), and here we looked for emotive signs in these three stories. Carys exclaims that her course 'was enjoyable', 'brilliant!' and, later, that she 'is not afraid of it [STEM] anymore'. She did not explain the roots of her past fear, nor did we pursue this. However, such emotions are certainly evident in the wider literature surrounding STEM, and not least in the advent of 'maths phobia' (e.g., Campbell-Montalvo et al., 2022). Philip felt under siege, not from science and technology itself but from his daughter's ferocious response to the demise of her dog. His strategy of 'getting to know the science of plastics' was a means to temper and redirect Amy's fire. Mehr, in turn, seems to have a 'slow burn' affair with STEM, which has surfaced

in homeworking with her children. There are no direct references to emotions in her story, but the overall picture in her narrative is one of long-term pleasure and engaged challenge in STEM, and of a shift away from the childhood perception of not being recognised as a STEM person to that of a STEM enthusiast.

### Pictures of non-linear success

Our montage sequence illustrates the successes of our three respondents' non-linear pathways into STEM. In our book 'Learning to succeed in sciences' (Salehjee & Watts, 2023), we point to the many ways people count success, from large-scale recognition and awards to small-scale feelings of contentment and satisfaction, and we see some of these here. Carys understands she will never speak French like a Parisian, or 'speak science' like a scientist. She is, nevertheless, happy to forge her own route to understanding within the 'whole new world' opening up to her. She is becoming familiar with air-monitoring technology and the logic behind experimental testing, conscious of a critical audience for any results that emerge from her work with the children. Philip saw the Pembroke beach clean as a success and takes pride in his newly activist daughter. Mehr sees a form of delayed gratification, taking pleasure in her children's enthusiasm as much as her own reinvigoration through STEM activities.

### Timelines and the importance—or not—of mid-stream entry

How have Carys, Philip and Mehr's definitions and perspectives developed and changed? Does STEM 'come of age' in people, or do people 'come of age' in STEM? STEM is neither static nor singular, nor are our three respondents. While each of them has been an 'early' STEM leaver, having disconnected from STEM at a relatively young age, they had also reconnected in several different ways. These have resulted from their life choices. Carys and Philip both have transformative moments that galvanise a new interest in matters STEM. Mehr has a much longer association through an enjoyment of problem-solving. The urge to learn 'informal STEM', therefore, is neither age-restricted nor has a set timeline. This can be sparked later in their lives via unavoidable situations and events, leading to a longer road to STEM learning. But in all, the personal desires and aspirations in satisfying their STEM urge determine when and how long this learning will take, whether in one stretch or in various short spells. Consequently, each individual gives us a different starting point and particular story timeline, so our contemplation of their montage is unique.

## CONCLUSION: SOME OUTCOMES FOR STEM EDUCATION

So, what, then, of our 'pictures of persuasion'? First, one outcome of our work is a challenge to the rather tired metaphor of the leaky STEM pipeline, hopefully to be replaced by a new one. One possibility is an image of a motorway system with no single starting point, multiple possible destinations, seamless on- and off-ramps, and parking places and 'pit stops' along the way. Thinking along these lines through individuals' STEM stories allows us to see people as autonomous, self-directed, self-aspired, self-time-lined STEM travellers, engaging in 'free-choice' STEM learning (Falk & Dierking, 2019), entering and leaving the STEM motorway system as and when they like. In their paper, Falk and Dierking (2019) place reliance on the many out-of-school institutions such as museums

and galleries, which might, from this perspective, be envisaged as 'STEM service stations', with skilled service attendants there to help. During the interviews, we often feel like co-travellers alongside Carys, Philips and Mehr (in this case) by sharing enthusiasm towards the issues we discuss. However, whether en route with our respondents or not, we keep our thoughts and interpretations guarded by our sense of self-positionality and need for 'invalidity proofing'.

Second, we draw attention to successful STEM identity development among 'late-onset' or 'mid-life' STEMers. Our three case studies illustrate the extent to which they use multi-modal sources in assembling their ideas and, as such, grow in confidence and self-sufficiency, and their abilities to find out. In their 2019 paper, Falk and Dierking warn,

> Profound changes are occurring in society, disrupting current systems and institutions; these disruptions are also affecting science education practice and research. Science learning is becoming a lifelong, self-directed process, dominated by out-of-school, free-choice learning experiences
>
> (Falk & Dierking, 2019, p. 1).

We see some of this pro-STEM free-choice learning culture in our three case studies. They are, we suggest a validated montage curated during the progress of the research study.

Third, in tune with Falk and Dierking, we argue for new forms of conducting and presenting educational research. In our view, we need to seriously consider all ages, informal contexts and cumulative/montaged subjective perspectives contextualised within particular spatial and environmental situations. These more nuanced understandings may be uncovered through narrative inquiry and other interpretative approaches. Moreover, this montage approach allows us to provide different flavours of the same phenomenon sensed at different intervals. A montage approach allows us to set instances and descriptions side by side to illuminate their complex, often contradictory and unpredictable ways of knowing. The implications of this study also warrant further research and are potentially of particular interest to policy, for example, the British Government's recommendations to improve 'the STEM skills pipeline' (UK Parliament, 2025, p. 1). This research will also be of interest to STEM educators and researchers, who can extend their work by employing late-onset STEMers and by adopting or adapting the construction of STEM stories and story montages to critique and address issues in STEM education. Above all, this study will provide confidence and encouragement to the general public to return to STEM even after they have long left STEM education.

## AUTHOR CONTRIBUTIONS

**Mike Watts:** Conceptualization; methodology; data curation; formal analysis; validation; investigation; writing – original draft; writing – review and editing; project administration. **Saima Salehjee:** Conceptualization; methodology; data curation; investigation; validation; supervision; writing – review and editing; writing – original draft; formal analysis; project administration.

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## DATA AVAILABILITY STATEMENT

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

## ETHICS STATEMENT

The College of Business, Arts and Social Sciences, Brunel University London, has approved the ethics application for this study in November 2022. The reference number is 40570-MHR-Nov/2022-42152-2.

## CONSENT TO PARTICIPATE AND PUBLICATION

The participants completed the consent form before the data collection. The participants consented to their interviews being published using pseudonyms.

## AI USE DECLARATION STATEMENT

During the preparation of this work, the author(s) used Grammarly to assist in the research and writing process. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication. The authors elect not to share data. Research data are not shared.

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