Demystifying the English bias in science: exploring the factors influencing bilinguals' uptake of STEM subjects in minority language education

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Abstract

in minority language contexts, schools are constantly having to negotiate between the competing demands of minority language maintenance on the one hand, and the all-encompassing privilege of English in certain subject areas on the other. This dilemma is exacerbated in domains where English is seen to have a global tradition. Whilst the prevalence of English in STEM-related fields is well established, less is understood about the opportunities to study these subjects in languages other than English. Exploring the extent to which an English bias may influence pupils' conscious choices around the study of STEM-related subjects can help inform school language policies and practices. Likewise, understanding how pupils negotiate the linguistic choice dilemma can help identify ways of supporting pupils' engagement with these subjects and help address some of the limitations of a monolingual teaching approach for bilingual pupils. This study examined pupils' likelihood of studying STEM-related subjects in Welsh-medium secondary schools in Wales, their linguistic choices around these subjects and their attitudes towards learning such subjects in English and/or in Welsh. The results revealed a general impression among pupils of the importance of English for STEM, which, mediated by their own linguistic backgrounds, abilities and experiences, influence pupils' linguistic choices and desires to various extents, particularly at the latter stages of education. Since the propensity towards monolingual engagement with these subjects – in Welsh or in English – may limit the scope for scaffolding their learning across languages and the benefits that incur, we propose alternative bilingual approaches to STEM-related subject teaching.

1. Introduction

It has been suggested that 72% of all British businesses rely on individuals with STEM[1]-related skills (Confederation of British Industry (CBI), 2014 as cited in Welsh Government, 2016). Yet, fulfilling this needs-based demand is a challenge (McDonald & Waite, 2019; Waite & McDonald, 2019; Bell, 2016). The apparent shortage of STEM-related expertise within the workforce contributes one of the biggest economic problems facing the UK Government today (House of Commons, 2018; Bevins et al., 2011). In 2014, 53% of employers expected that they would continue to experience problems in recruiting individuals with relevant skills over the coming three years (CBI, 2014, as cited in Welsh Government, 2016). Much of this shortage may be rooted in pupils' experiences of and engagement with STEM-related subjects in education. Schools therefore have a key role to play in enthusing pupils about STEM-related subjects, concepts and professions, in developing subject proficiency, and in delivering pupils who can continue with their training beyond statutory education and help meet the growing workforce requirements.

However, in minority language contexts, schools are constantly having to negotiate between the competing demands of minority language maintenance on the one hand, and the all-encompassing privilege of English in certain subject areas on the other. This dilemma is exacerbated in domains where English is seen to have a global tradition – where English is assumed the language of mobility, the language of internationalisation and the language of status (Berg et al., 2001) – and where English holds a dominant position as the language of rigorous scientific publication (Ferguson et al., 2011; Hanauer & Englander, 2013; Lillis & Curry, 2010; 2013; Liu, 2017; Plo Alastrué & Pérez-Llantada, 2015). Whilst the global prevalence of English in STEM-related fields is well established, less is understood about the opportunities to study these subjects in languages other than English. Conversely, more is known about the challenges surrounding the English bias in STEM-related fields (see below). School-based initiatives to increase pupil uptake of STEM-related subjects may help increase engagement with these subjects and develop capacity within the workforce in the long term; that said, such initiatives are rarely likely to result in expanding the study of these subjects beyond the realms of English. Access to mother tongue education is important

[1] STEM, in its tradition sense, refers to Science, Technology, Engineering and Mathematics. Since teacher shortage is also present in STEM-related fields, such as computer science and various technology subjects, we use STEM in its broader sense throughout this paper and refer to STEM-related subjects where necessary.

(Nishanthi, 2020), but largely challenged in many regions of the world (Romaine, 2013). Within stable bilingual communities where a minority language co-exists with a more dominant, societal one, providing access to minority language education is essential in order that the language can flourish within a truly bilingual society (Peace-Hughes, 2022). Fostering the ability to discuss academic subject matter in more than one language has both academic (Brutt-Griffler & Jang, 2019) (see also below) and cultural/societal implications (Lang-ay & Sannadan, 2021), and helps diversify the domains in which the language is relevant (Davies & Trystan, 2012). In fact, parents often choose minority language education for their children for cultural reasons such as social integration with tradition and heritage (e.g., Bush et al., 1984; Hodges, 2012) rather than socio-economic reasons (although see O'Hanlon, 2015). Ensuring that pupils have the opportunity to study subjects through a minority language is therefore important, and has implications for cultural and linguistic sustainability (Becerra-Lubies et al., 2021). Within the STEM context in particular, this means fostering the ability to discuss STEM subjects in Welsh on both an academic platform and in interactions with the general public (e.g., as a medical practitioner).

However, the very presence of a linguistic dilemma around these subjects at school may only serve to trigger subject avoidance behaviour, doing very little to support workforce and societal demand. Exploring the extent to which such bias may influence pupils' conscious choices around the study of STEM-related subjects, and how pupils negotiate the linguistic choice dilemma, can help inform school language policies and practices to better support pupils' engagement with these subjects. To date, very little is known about pupils' own role in the linguistic choices they make at school, particularly around subjects in secondary education system (O'Hanlon, 2015).

Consequently, the purpose of this study was to examine pupils' likelihood of studying STEM-related subjects in Welsh-medium secondary schools in Wales, their linguistic choices around these subjects and their attitudes towards learning such subjects in English and/or in Welsh. To our knowledge, this is the first paper to look specifically at pupils' views around studying STEM-related subjects in a minority language context where it is possible to study these subjects throughout statutory education in a language other than English. Whilst there are some studies that have explored parents' reasons for enrolling their students in Welsh-medium education (see below), very few have explored pupils' opinions, particularly at secondary school level.

We begin with an overview of the linguistic nature of secondary schools in Wales, followed by a discussion of secondary school qualifications and subject selection processes in Wales. This is then followed by a review of the challenges to STEM-related teaching in the Welsh context, including teacher shortage and the perceived English bias in STEM-related fields. We then present the findings of a survey carried out with secondary school pupils exploring their engagement with STEM-related subjects in English and/or in Welsh, and offer some recommendations for future pedagogical interventions.

1.1 The linguistic nature of secondary schools in Wales

According to the 2011 Census data, 8% of individuals living in England and Wales speak one of 600 languages other than English as their main language, with *Cymraeg* (Welsh) being the most common of those, totalling 562,016 speakers at the time. Welsh belongs to the Brythonic branch of the Celtic family of Indo-European languages, and is currently spoken by 538,300 people aged three years or older, which equates to 17.8% of the population of Wales (Office for National Statistics, 2023).[2] Despite its long-term encroachment by English, Welsh has continued to flourish in various ways, albeit as a minoritized language. More recently, Welsh gained legal status in Wales following the passing of the Welsh Language (Wales) Measure (2011),[3] providing legislative protection for the language.

One of the key successes to language revitalisation efforts in Wales has been the provision of Welsh, either as a medium of instruction or as an obligatory subject, in schools across Wales. Since 1999, all children attending government-maintained schools in Wales must learn Welsh, at least as a subject, up to age 16. Ever since the first Welsh-medium primary school opened in 1939, followed by the first bilingual Secondary School in 1956, the number of Welsh-medium and bilingual schools has continued to grow, most prominently in the primary sector, but increasingly so in the secondary sector, which is the focus of this paper. This growth has, to a great extent, stemmed from grass-root parental demand for Welsh-medium education for their children in order to ensure greater societal and linguistic integration, both for the purpose of linguistic maintenance and the preservation of cultural

[2] https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/language/bulletins/welshlanguagewales/census2021 retrieved 17.3.23

[3] https://www.legislation.gov.uk/mwa/2011/1/contents retrieved 12.3.24

heritage (Hodges, 2012) and for the additional benefits accrued from becoming bilingual (Bush et al., 1984).

During the 2020-2021 academic year, there was a total of 182 secondary schools in Wales, catering for 174,133 children (StatsWales, 2021a; 2021b). At that time, secondary schools in Wales were categorised as belonging to one of four[4] categories based on their respective levels of Welsh-medium provision. In Category 1 schools, all subjects, bar English, were taught through the medium of Welsh. However, at A-level (Advanced Level qualification for students aged 16-18), this provision often hinged on teacher availability in particular subject areas (Davies & Trystan, 2012; see below). When that occurred, post-16 provision in Welsh-medium schools mirrored the provision offered in Type A of Category 2 schools. Category 2 schools were bilingual schools, where both Welsh and English were used in the teaching (bar English and Welsh as subjects) to various degrees. In Type A Category 2 schools, one or two subjects were offered either in English or bilingually across the 11-18 age range, with the remaining subjects delivered in Welsh. Type B, Type C and Type D Category 2 schools offered most or a high proportion of subjects in either language – offering a choice of medium for the pupils – or delivered all subjects fully bilingually (Welsh Government, 2021, pp.10-11). In Category 3 schools, education was delivered predominantly through the medium of English but with significant use of Welsh. In Category 4 schools, English was the main medium of teaching and Welsh was taught only as a second language subject until the end of Key Stage 4 (age 16) (Welsh Assembly Government, 2007).

In 2020-21, the majority of secondary schools (72%, n=131) were classified as Category 4 (English-medium) schools, catering for 77% (n=133,743) of the secondary school-aged pupil population, with a further 4% of schools (n=7) classified as Category 3 (predominantly English-medium) schools, catering for 3% (n=5716) of the pupils. Only 18 schools (10% of schools) were classified as Category 1 (Welsh-medium) schools, catering for 9% (n=15,879) of the pupils. The remaining 26 schools (14% of all schools) were one of four sub-groups of Category 2 (bilingual schools), catering for 11% (n=18,795) of the pupil population. This means that around 21% of schools (n=44) offered at least half of their

[4] During the data collection phase of this study, schools were categorised according to the regulations outlined in Welsh Government (2007) - "Defining schools according to Welsh medium provision" https://gov.wales/sites/default/files/publications/2018-02/defining-schools-according-to-welsh-medium-provision.pdf (retrieved 12.1.22). However, in 2022, a new categorisation system was launched to become operational during the 2022/23 academic year.

curriculum through the medium of Welsh to 20% (n=34,674) of secondary school aged pupils.

Within Welsh-medium secondary schools, 78% (n=12,320) of pupils were considered to be fluent in Welsh, with a further 4% (n= 690) viewed as being able to speak Welsh but not fluently. Among the 12,320 that were considered fluent, 37% (n=4,565) spoke Welsh at home, with a further 59% (n=7,310) not speaking Welsh at home. The remaining 445 selected 'non-applicable' suggesting that 4% of fluent Welsh speakers spoke a language other than Welsh or English at home. Among the 690 who could speak Welsh but were not fluent, 29% (n=200) spoke Welsh at home, 55% (n=390) did not. The remaining 100 selected 'non-applicable' suggesting that 14% of non-fluent Welsh-speakers spoke a language other than English or Welsh at home (StatsWales, 2021c). Many pupils attending secondary schools in Wales are therefore fluent bilinguals who can study through the medium of Welsh or English, where the option is made available to them. However, the linguistic options, particularly at A-Level, vary, as noted below.

1.2 Secondary school qualifications and subject selection in Wales

Education is compulsory in Wales for children between the ages of 4 (Reception Year) and 16 years (Year 11). Students normally transition from the primary to the secondary sector at age 11 (moving from Year 6 primary to Year 7 secondary) and are required to sit statutory examinations – General Certificate of Secondary Education (GCSE) – at age 16. Students normally sit a minimum of 9 GCSEs, of which English, Welsh first language/Welsh second language (depending on the type of school), Mathematics, and Science are compulsory subjects. The remainder of the GCSE subjects taken are chosen from among the options that are available at a given school. These options may include the humanities, such as History, Religious Education or Geography; a Modern Foreign Language; technical subjects such as Design and Technology, Food Technology or Computer Science; or arts subjects such as Music, Art, Drama, Media Studies. Whilst partaking in physical education is also compulsory up to age 16, students can also opt to study Physical Education as a GCSE subject option.

Beyond Year 11, when students sit their GCSE examinations, students have the option to continue with their formal education at school if the school has a 6th Form, or they may attend a local 6th Form College where such provision exists, where they will study for

their A-Levels (Advanced Level qualifications). In Wales, A-Level qualifications are the normal prerequisites to university enrolment. Students who do not wish to pursue university qualifications can alternatively opt to enter Further Education to gain more vocational qualifications. Students who opt to continue through to 6th Form normally study a minimum of 3 A-Level subjects, all of which are optional, pending logistical issues (such as timetabling and class size) and teacher expertise. This means that students get to choose which subjects they study, which are often influenced by the subject area they wish to pursue at university or as a career, the subjects they most enjoy, or the subjects they are likely to succeed with the most.

For those students attending Welsh-medium or bilingual secondary schools in Wales, an additional consideration when making subject choices is the language of study. Very few studies have looked specifically at pupils' choices around the language of their education, particularly in relation to their choices at secondary education. For example, Gruffudd et al. (2004) (as cited in O'Hanlon, 2015) revealed how parents reported that their child's linguistic choices in moving from primary to secondary education typically followed the choices made by their friends. O'Hanlon (2015) conducted a comparative study of parents' and their children's linguistic choices when moving from Welsh-medium or Scottish Gaelic-medium primary to secondary school, and the rationale underpinning those choices. She found that whilst parents in Wales rooted their choices around the socio-economic benefits of future employment, pupils tended to draw on their knowledge of their older siblings' and their own parents' experiences of Welsh-medium education in making their choices. Pupils expressed a preference for being educated in Welsh than in English, they expressed a wish to continue to be educated alongside their friends, demonstrated recognition of the importance of Welsh as part of their heritage, they were aware of the quality of Welsh-medium education, and were also aware of the socio-economic benefits that it conferred. Whilst other factors such as students' perceptions of their own linguistic ability may play a role in such decisions (see, e.g., Pierce, 2024), there are additional, linguistic and non-linguistic factors that challenge the delivery of Welsh-medium provision in STEM that may influence students' willingness to study STEM subjects through the medium of Welsh. These factors are outlined below.

1.3 Challenges relating to the teaching of STEM in a minority language

Teaching STEM-related subjects is challenged by many factors, including teacher shortage (Asia Society, 2012; Hutchison, 2012; See & Gorard, 2019), gender inequalities (De Nicola & D'Agostino, 2021; Masanja, 2010; McNally, 2020), and pupils' perception of the complexity and relevance of the subjects for their future careers (Brown et al., 2008; Owen, 2017; Welsh Government, 2012). In minority language contexts, two further challenges include (i) obtaining teachers with both the subject expertise and the linguistic skills to deliver the content effectively, and (ii) the perceptions of prestige around English for STEM-related study and careers. These are discussed below.

1.3.1 Teacher shortage

Teacher shortage in STEM subjects has been observed in many regions of the world, most notably in the US (e.g., Feder, 2022; Hutchison, 2012; Lembo, 2016). In Wales. this issue is exacerbated further by the continuous shortfall in the number of Initial Teacher Education (ITE) students who choose to train as STEM teachers:

> The number of post-graduate science teachers being trained has fallen short of national targets over several years (Estyn, 2017, p. 6).

During the 2019-2020 academic year, only 55 students were recruited to train as science teachers throughout Wales (20 in Biology, 20 in Chemistry, 10 in Physics and five in General Science) (StatsWales, 2022). This fell significantly below the target figure of 142 noted during the 2016-2017 academic year (Statistics for Wales, 2017), with only five of said students (all of which were recruited to train in Chemistry) also pursuing their training through the medium of Welsh (Statistics for Wales, 2021). Whilst the recruitment rate to science ITE places in Wales was at 65% in 2016-2017 (where 86 students were recruited; 35 in Biology, 31 in Chemistry and 20 in Physics), in England, where there are various pathways into the teaching profession, a much higher rate of 81% was achieved (Estyn, 2017, p.33).

Tackling the shortage in qualified teachers means tackling the shortfall in ITE recruitment. However, in order to tackle the shortage in ITE recruitment, pupils need to be enthused about science and the teaching of science, so that they themselves decide to progress with the study STEM subjects beyond school with a view towards training to teach. This issue is of particular relevance in the Welsh-medium context, most notably in rural and western areas of Wales where the greatest proportion of Welsh-medium provision is found:

> Generally, there is a lack of applicants for science posts and recruiting to Welsh-medium science departments is a particular problem (Estyn, 2017, p.6).
>
> …there are not enough applicants for science teaching posts across Wales… Recruiting to Welsh-medium science departments is particularly challenging (Estyn, 2017, p.33).
>
> …schools in more remote parts of Wales experience the greatest difficulty in recruiting and retaining staff (p.33).

The retention of STEM teachers in remote regions is not limited to Wales. Similar challenges have been reported in rural education in Indiana (Goodpaster et al., 2012). However, where posts are filled, either on a short-term basis (via supply teachers), or on a more permanent basis, they are not always filled by suitable candidates:

> Even where schools are more successful in recruiting staff, the number of high-quality applicants is low. There are fewer applicants for physics posts than for biology or chemistry. There are very few suitable applicants for advertised posts…
>
> A minority of departments visited in this survey have experienced difficulties with long-term absenteeism of staff. Supply teachers for science who can teach through the medium of Welsh, especially in rural parts of the country, are in very short supply. As a consequence, schools will often employ a non-specialist supply teacher to cover science lessons.
>
> When science staff are absent, many schools have to employ non-specialist supply teachers to cover their lessons, especially in key stage 3.
>
> (Estyn, 2017, p.33)

Related to this, pupils in Wales continuously perform worse on the OECD's Programme for International Student Assessment (PISA) science tests than their counterparts in England, Scotland and Northern Ireland (Jerrim & Hure, 2016). Despite this trend, when comparing schools across Wales, pupils in Welsh-medium schools outperform pupils in English-medium schools at science, although this may be, in part, due to the lower proportions of pupils that are eligible for free school meals[5] in Welsh-medium contexts (see also Jones, 2017):

[5] In the absence of reliable measures that are often used to classify socio-economic status (SES) in more populated areas of the UK (e.g., residential postcode), whether a child is eligible for free school meals is often used as an indirect (or proxy) measure for SES in Wales.

> Performance of pupils in Welsh-medium schools in science at levels 1 and 2 is better than that for pupils in English-medium schools for the last five years (Welsh Government, 2017c & 2017d) (Estyn, 2017, p.13)

> Performance at level 5 or above, level 6 or above and level 7 or above in science has been better in Welsh-medium schools than in English-medium schools since 2012 (Welsh Government, 2017b & 2017c) … performance in Welsh-medium schools continues to be above that in English medium schools in 2017 (Estyn, 2017, p.35).

Despite these optimistic patterns within Welsh-medium schools in particular, the paucity of suitably qualified teachers is not ideal, and impacts directly on pupils' engagement with these subjects:

> Pupils consulted during this survey expressed their concern that supply teachers are unable to help them with their work, carry out practical work or assess their work meaningfully. This impacted on their progression and enjoyment of the lessons (Estyn, 2017, p.33).

Given the complexities of the current situation, it is worth exploring different solutions to this shortfall. For the purpose of this study, we focused on identifying some of the factors influencing pupils' willingness to study STEM subjects through the medium of Welsh, English or bilingually.

1.3.2 English bias in science

It is widely recognised that English holds a global position as the *Lingua Franca* in STEM-related fields (Sano, 2002). This is most notably reflected in the dominance of English in academia – in scientific publications, in grant applications, in conference presentations, etc. (Ferguson et al., 2011). Whilst the dominance of a single, mutually intelligible language has its merits in terms of ensuring inward and outward mobility, cross-cultural and international collaboration, and the ability to understand, reference, learn from and build upon each other's work (see, e.g., House, 2003; O'Neil, 2018), such a monolithic approach challenges a number of important issues (for a thorough discussion see Navarro et al., 2022). First, a monolingual approach to academic study unquestionably threatens the very existence of other languages by virtue of its diminished domain for language use (Ferguson et al., 2011). Second, although English is commonly cited as the most widely spoken language in the world, it is mainly spoken by non-native speakers, to the extent that it has been suggested that the number of non-native speakers of English will

outnumber native speakers of the language by 50% by 2060 (Crystal, 2003). Having English as a Lingua Franca for the STEM subjects may provide an unfair linguistic advantage for those who are native speakers (Pronskikh, 2018). Third, over-reliance on scholarly outputs produced only in English may lead to an underrepresentation oof knowledge in certain domains, particularly when equally competent scholars publish high quality work in languages other than English (see, e.g., Ammon, 2006).

In education, a further challenge relates to the extent to which STEM-related subjects are assumed to be language neutral due to their reliance on symbolic representations of knowledge. However, whilst subjects such as mathematics and physics use internationally recognised symbols (e.g., Σ, ∫, ∷, √, ≈) the understanding that happens around these symbols involve complex use of language (e.g., summation, integral, averaged with, square root, is approximately equal to, etc.), and it is in these additional linguistic discussions around these symbols that meaning is developed. Similarly, whilst subjects like chemistry have adopted international standards for element names and symbols within the Periodic Table, element names and symbols can vary according to language. These discussions and expressions around common concepts become increasingly complex over time:

> …in the science classroom English language learners are faced with the double challenge of acquiring subject matter and skills through a language that they have not yet fully mastered. The abstract language used in the science classroom is an obstacle for the majority of these students as the language and its vocabulary become increasingly complex… hence the need to use a language students have high proficiency in (Charamba, 2020, p.659).

The ability to fully grasp and discuss these subjects are therefore likely to be contingent on good receptive and expressive language skills. In multilingual contexts, the ability to appreciate the intricate nuances of the application of knowledge in various languages is clearly important; denying pupils access to knowledge through the use of their first or strongest language may ultimately lead to incomplete acquisition of knowledge (Martin et al., 2012; Van Laere et al., 2014).

Having sufficient levels of understanding of the language being taught is therefore essential for the development of knowledge in these subjects, particularly if they are taught

monolingually. However, an alternative model to monolingual, English only or 'other language only' delivery is one where both languages are involved in the teaching, where the pupil's strongest language can provide a facilitatory role in supporting learning through their weaker language (Meyer, 2008). Such a model may ultimately lead to subject knowledge and ability to discuss subject content in both languages. One such model is where the L1 is involved in the learning process to scaffold L2 learning.

1.4 The facilitative role of an L1 in the L2 classroom

Numerous studies have shown that allowing pupils access to their L1 when (i) learning another language (Auerbach, 1993; Littlewood & Yu, 2011; Storch & Aldosari, 2010) and (ii) when learning through another language (Coyle et al., 2010; Lewis et al., 2012; Swain & Lapkin, 2000) can be beneficial for pupils. In STEM-related subjects in particular, studies have shown that learning in a bilingual environment leads to stronger acquisition of certain skills than learning in a monolingual context (Gajo & Serra, 2002; Tavares, 2015). Even in contexts where pupils study STEM-related subjects in their home language or in English, either through choice or because of the medium of instruction at the school, it is possible to ensure pupils are aware of the terminology and subject-specific scientific phrasing in both languages through engaging with bilingual pedagogical methods. One such method that has its roots in the bilingual Welsh-English classrooms is translanguaging, which '...alternates the use of [Language A] and [Language B] for input and output in the same lesson' (Cenoz & Gorter, 2017, p. 311; see also Williams, 2002 for an example of where a science teacher included elements of translanguaging).[6] Through the exchange of meaning relations across languages, methods such as translanguaging lead pupils to process information at a deeper level (Baker & Wright, 2021). This process enriches their language development, develops

[6] We adopt the traditional definition of translanguaging here, reflecting how the concept was initially developed within the Welsh language context (Williams, 1994). Whilst the original focus was on the development of effective pedagogical practices that alternated languages within the classroom, the term has since undergone both theoretical and conceptual changes (Cenoz & Gorter, 2021; Singleton & Flynn, 2022). Alternative conceptualisations of the term focus on the individual and their fluid use of their entire linguistic repertoire in their learning (Otheguy et al., 2015), although some have questioned the theoretical underpinnings of this approach (Cummins, 2022). Regardless of one's theoretical persuasion, the extended definition of the term challenges some of the aims of minority language education (see Fortune & Tedick, 2019 and McPake & Tedick, 2022 for exploration of translanguaging practices in immersion education settings). For that reason, we adopt the more pedagogical-driven definition of the term here, which encourages engagement and learning through a minority language (within the context of language revitalisation), but where the input language may vary.

their verbal communication and literacy skills in their weaker language, and helps integrate L1 and L2 speakers within the same learning environment (Jones & Lewis, 2014). A further advantage is that it offers the opportunity for monolingual parents to discuss and contribute to their child's schoolwork when that work occurs in a language they do not understand, as translanguaging leads to the processing and communication of information between languages (Baker & Wright, 2021). However, whilst there are numerous benefits to bilingual teaching of this type, such methods have tended to occur in relation to humanities subjects as opposed to STEM subjects (Thomas et al., 2018), rendering STEM subjects largely driven towards monolingual English instruction in many cases.

1.5 The current study

In order to explore some of the factors that influence pupil choice around the linguistic medium of study in these subjects, we surveyed the opinions of school pupils who had either opted or not opted to study STEM subjects at A-level (age 16-18 years) or who were currently learning STEM-related subjects as compulsory subjects at GCSE (age 14-16 years) and who were currently considering their options for the post-16 sector. These pupils attended Welsh-medium or bilingual secondary schools in Wales where the options to study these subjects in Welsh, English or bilingually varied from one context to the next. Their opinions around the likelihood that they would choose to study these subjects at university were also sought, including their opinions around their likelihood of studying these subjects in Welsh, English or bilingually at university and their opinions around the usefulness of bilingual skills in STEM-related careers. Since the purpose was to explore the reasoning behind students' linguistic behaviours, the study adopted a constructivist, grounded theory approach to the research, set around the following broad research question:

> What factors influence bilingual Welsh-English pupils to study STEM/STEM-related subjects at school and/or at university through the medium of Welsh, English or bilingually?

Together, their responses provide valuable insights into some of the reasoning behind their linguistic choices around STEM.

2. Methodology

2.1 Participants

All Category 1 and 2 secondary schools in north Wales (n=18)[7] were given the opportunity to contribute to the study. For various reasons relating to staffing issues, engagement with other research surveys, and upcoming school inspections, only five schools were able to provide their time to fully engage with the study at the time of data collection. These schools represented the counties of Wrexham (where 12.2% of the population spoke Welsh), Conwy (where 25.9% of the population spoke Welsh) and Gwynedd (where 64.4% of the population spoke Welsh) (Office of National Statistics, 2023). Across the five schools, data were collected from 76 pupils. Surprisingly, however, whilst 18% (n = 14) of the respondents were male, 82% (n = 62) were female. In the context of STEM education, where gender differences are often highlighted (Department for Education, 2019), often in favour of males (Halpern et al., 2007; Hill et al., 2010; Nagy et al., 2008), this higher proportion of female respondents needs to be taken into consideration when interpreting the findings. The majority of the pupils (40%, n = 30) were in Year 9 (age 13-14 years), with 30% (n = 23) of respondents in Year 10 (age 14-15 years), 15% (n = 11) in Year 11 (age 15-16 year), and 12% (n = 9) and 4% (n = 3) in Years 12 (16-17 years old) and 13 (17-18 years old) respectively.

Given the variation in Welsh-medium provision across Category 2 schools, the increased introduction of English as a medium of instruction at GCSE and A-Level in some Category 1 schools, and the variation in pupils' linguistic experiences based on the linguistic choices they make (where applicable), pupils were asked to categorise how their schools used Welsh and English in order that we could compare responses according to their experiences. Just under half of the pupils (46%, n=35) attended bilingual schools where Welsh and English were used equally. A further 33% (n=25) attended schools where Welsh was used either mostly or as the sole medium of instruction, while the remaining 21% (n=16) attended schools where the medium of instruction was mostly English (see Table 1 below). In comparison, the majority of pupils (64%, n = 49) reported that they used English as a social language, either solely (7%, n=5), mostly (34%, n=26) or in conjunction with

[7]Each region of Wales has its own linguistic challenges. However, as the majority of Category 1 and 2 secondary schools are located in north Wales, and are supported by the same Regional School Improvement Consortia, we opted to focus our study on that region.

Welsh (24%, n=18). Only 36% (n=27) of pupils used Welsh mostly or solely as a language for social purposes.

Table 1: Proportion of pupils according to home language backgrounds, medium of instruction at school, and use of language in social contexts

	English only	English mostly	Welsh and English equally	Welsh mostly	Welsh only
Home language	22% (n = 17)	16% (n = 12)	20% (n = 15)	8% (n = 6)	33% (n = 25)
School language	0% (n = 0)	21% (n = 16)	46% (n = 35)	25% (n = 19)	8% (n = 6)
Social language	7% (n = 5)	34% (n = 26)	24% (n = 18)	24% (n = 18)	12% (n = 9)

The sample of pupils was therefore representative of a range of home language backgrounds and included pupils who used both Welsh and English to various degrees within their social circles.

2.2 Data collection

2.2.1 Data collection tools

Electronic questionnaires were used to collect the data. The data presented here were part of a larger study that explored the views of a range of stakeholders – teachers, pupils, university lecturers, university students – to a variety of questions, including their views on a combined science degree. The pupils' questionnaire included 23 questions. A variety of types of questions were used, including statements set on a 5-point Likert-type rating scale, open questions, and multiple-choice questions. The questions explored the extent to which pupils were interested in pursuing STEM-related subjects within statutory education and beyond, any potential barriers that hindered their choices, and their attitudes towards studying these subjects through the medium of Welsh. All questionnaires were shared with the Local Education Consortia's Supporting Improvement Advisors for STEM to gain their feedback before the final versions were disseminated.

2.2.2 Procedure

Approval for the study was obtained by the School of Education's Ethics Board. The study followed the ethical protocols for conducting on-line questionnaires with pupils as outlined

in BERA Ethical Guidance for Education Research (2018)[8]and the BPS Code of Ethics and Conduct (2021)[9] and adhered to GDPR guidance. All Welsh-medium and bilingual secondary schools within the north Wales region were invited to participate in this research. When invited to participate in the research, all potential participants were given an information sheet that explained what the research entailed and what would be expected from them as participants. Following an agreement to take part, they were sent a link to an online questionnaire, which enabled the participants to provide informed consent for their participation, and to complete the questions, completely anonymously, at a time and location that suited them.

2.3 Data analysis

2.3.1 Survey data

Responses to the Likert-type value statements were treated as ordinal data (Harpe, 2015). Each scale varied in terms of how the value statement was narrated, depending on the nature of the question (e.g., strongly disagree – agree strongly; very important – not important at all). Each value statement was assigned a numerical value ranging from 1 = most disagreeable response to the statement and 5 = most agreeable response to the statement – e.g., 1 = not useful at all, 2 = not very useful, 3 = not sure, 4 = quite useful, 5 = very useful. Results were analysed for distributional tendencies across the variables of interest using the Chi square (χ^2) test (Franke et al., 2012).

2.3.2 Narrative data

The narratives provided via the open-ended questions were subjected to thematic analysis (TA) (Braun & Clarke, 2006), with conscious adherence to the principles of reflective TA (Braun & Clarke, 2019). After multiple readings of the narratives, recurring points and isolated instances were coded, and the codes were collated into broad themes by the researcher. Subsequent reviews of the coding and discussions among the broader research team led to the further development and refinement of the themes, as presented below.

[8] https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018-online retrieved 12.3.24

[9] https://explore.bps.org.uk/content/report-guideline/bpsrep.2021.inf94 retrieved 12.2.24

In what follows, all direct quotations from open-ended questions are reported verbatim.

3. Results

The results gained from both the quantitative and qualitative data sets are presented together under four broad elements that were addressed in the questionnaire: (i) choices around STEM-related subjects at school; (ii) choosing STEM-related subjects at University; (iii) career choices; and (iv) attitudes towards Welsh-medium STEM education. These are discussed below.

3.1 Choices around STEM-related subjects at school

3.1.1 Choice of language

Approximately half (55%, n = 37) of the participating pupils agreed that they were able to choose whether they study their STEM subjects in Welsh, English or bilingually. Of those who were allowed to choose the medium of instruction, the majority 46% (n = 17) chose to study these subjects in Welsh, while 27% (n = 10) decided to study in English, and the remaining 27% (n = 10) were able to choose to study them bilingually.

While there was no significant pattern between the gender of the pupils and their choice of language, pupils from different backgrounds opted to study in their home language to different degrees (x^2 (8, n = 45) = 30.097, $p < .001$). Eighty two percent (n = 9) of the pupils who spoke English at home chose to study their subjects in English, 58% (n = 7) of those who spoke both Welsh and English at home chose to study their subjects bilingually, while 68% (n = 15) of the pupils who spoke Welsh at home chose to study the subjects through the medium of Welsh. These results suggest that the language spoken at home does not necessarily mirror the linguistic choices pupils make in school around STEM subjects, particularly for those who speak Welsh either exclusively or alongside English in the home. However, if they spoke English at home, they are very likely to opt to study through the medium of English.

The rationale provided for their linguistic choices in relation to STEM-type subjects differed across pupils and across linguistic group. These reasons are discussed below, first, in relation to those that chose to study bilingually, and second, in relation to those that chose to study monolingually (in Welsh or in English).

Bilingual.

Four clear themes emerged as reasons why pupils opted to study bilingually. These included L1-L2 facilitation, future reference, flexibility and bilingual benefits, and are discussed below.

Some pupils chose a bilingual route (where such provision was available) in order to ensure complete understanding of the content. In such cases, English was used to support their access to the curriculum in Welsh:

> *If I did work in two languages I would understand better*
>
> *So that I'm still receiving my education in Welsh but can understand everything correctly*
>
> *At the moment I'm using nearly only Welsh in these subjects – especially Mathematics and Science, but it's hard to do additional research without the English vocabulary, so most of the time I need to do it on my own, without help – there is no-one at home with substantial Welsh skills.*

Another pupil related their choice to study bilingually to the need to be cognisant of the requirement to be able to access the subjects in both languages (or mainly in English) at university, but needing both later on in the workplace:

> *It's important to know the subject terms in both languages for University*
>
> *Because I really like the variety and the ability to adapt if needs be in the general work world.*

Others focused more on the versability of the bilingual learning process itself:

> *Because it's easier to do some things in different languages*
>
> *If you don't understand a word in Welsh you can see if you know it in English*

One pupil related their choice to the known benefits of bilingualism:

> *Because being bilingual is a bonus*

Overall, then, those who chose to study bilingually often did so strategically, with a view towards maximising their learning experience and opportunities for the future (cf. O'Hanlon, 2015).

Monolingual.

Of those who chose to study STEM-related subjects monolingually, many chose to study in their native/home language:

I think in the English language and speak English at home

Welsh is my first language and it's easier to remember things and to read stuff

My first language is Welsh, so it's easier for me to understand

Because I speak Welsh most of the time

Others based their choice on their learning experiences to date, with some remarking that relearning terminology and subject-specific information in another language may impact on their academic gains:

I've already studied all the subjects in Welsh so it would be difficult to learn in another language

I understand things better in Welsh & I've done all of my education in Welsh

Because I've already learnt the Science and Mathematics terms in English

I've learnt everything in Welsh so far, so it would be confusing

Because I've been learning things in Welsh

I've studied in Welsh throughout my life

As was noted among those who opted to study bilingually, many pupils made a strategic linguistic choice to study monolingually based on the language in which they felt they excelled, and the progression options beyond school:

It's easier for me and I'll be moving to an English college

Because not many workplaces use only Welsh. So it will be hard having an education just in Welsh and then needing to do it in English after school

Because there are an immense amount of opportunities to learning these subjects in English over Welsh in the long term

I'm more comfortable in English and English is the language used in most Science jobs

Helps with understanding and jobs in the future

There are more opportunities in Welsh

To get a job

3.1.2 Choice of subjects

Pupils in Years 12 and 13, and already pursuing their A levels, were asked whether they had chosen STEM-related subjects for their studies. From the 12 participants in those years, two (17%) had chosen biology, three (25%) had chosen chemistry, no-one had chosen computing, one had chosen design and technology (8%), three had chosen physics (25%) and four (33%) had chosen maths.

Pupils in Years 9 to 11 (13- to 14-years-old) were asked how likely they were to choose STEM-related subjects for their A levels. The results are noted in Table 2 below:

Table 2: Proportion of Y9-11 pupils likely to choose STEM-related subjects for A-level.

	Biology	Chemistry	Computing	Design & Technology	Physics	Maths
Not sure	2% (n = 1)	9% (n = 6)	10% (n = 6)	8% (n = 5)	11% (n = 7)	9% (n = 6)
Not likely	41% (n = 26)	38% (n = 24)	52% (n = 33)	41% (n = 26)	41% (n = 26)	34% (n = 22)
Small chance	17% (n = 11)	25% (n = 16)	21% (n = 13)	25% (n = 16)	17% (n = 11)	13% (n = 8)
Started considering	14% (n = 9)	9% (n = 6)	8% (n = 5)	11% (n = 7)	14% (n = 9)	19% (n = 12)
Good chance	11% (n = 7)	6% (n = 4)	6% (n = 4)	8% (n = 5)	11% (n = 7)	9% (n = 6)
Very sure that I will	16% (n = 10)	13% (n = 8)	3% (n = 2)	8% (n = 5)	6% (n = 4)	16% (n = 10)

The results in Table 2 indicate that the least likely STEM-related subject to be chosen at A-level was Computing (73% not likely or small chance) followed by Design & Technology (66%), Chemistry (63%), Biology and Physics (58% per subject) and finally Maths (47%).

Compared to the other subjects on offer, Biology (n=18), Physics (n=11) Chemistry (n=11) and Maths (n=19) were among the most likely subjects students were likely to pursue, alongside History (n=13), English (n=11), and Art (n=11). (See Table 3.)

Table 3: Subjects pupils said that they were likely to choose at A-Level.

Subject	No.	Subject	No.	Subject	No.
Health and social care	3	Computing	8	Chemistry	11
Physical Education	4	Physics	11	Childcare	1
Outdoor pursuits	1	Biology	18	Hair & Beauty	2
Geography	7	French	7	Welsh	9
Travel & Tourism	1	Design and Technology	8	History	13
Food Technology	4	Media studies	1	Psychology	3
Drama	9	Art	11	Business	2
Religious Education	6	English	11	Photography	1
Graphics	1	Engineering	1	Music	2
Maths	19	Sociology	1	Law	1
Mechanics	1				

Some of the reasons why pupils would choose these subjects included (i) their enjoyment of the subject, (ii) career requirements, and (iii) how easy they found the subjects. In relation to STEM-related subjects, pupils' home language seemed to have an effect on their choice of subjects with significances between their home language and Computing (χ^2 (20, n = 62) = 33.404, $p < .05$), Design and Technology (x^2 (20, n = 63) = 44.396, $p < .05$) and Mathematics (x^2 (20, n = 63) = 33.063, $p < .05$). Children from English-speaking homes seemed more inclined to choose these subjects than children raised in Welsh-speaking homes.

When asked in which language they would choose to study those subjects if they were allowed to choose between English, bilingual or Welsh, the results revealed a mixed picture (see Table 4 below).

Table 4: Proportion responses to the linguistic choices pupils would make if studying these subjects at A-Level

	Biology	Chemistry	Computing	Design & Technology	Physics	Maths
English	26% (n = 12)	27% (n = 13)	25% (n = 11)	14% (n = 6)	26% (n = 12)	19% (n = 10)
Bilingual	26% (n = 12)	29% (n = 14)	39% (n = 17)	36% (n = 15)	23% (n = 11)	38% (n = 20)
Welsh	49% (n = 23)	45% (n = 22)	36% (n = 16)	50% (n = 21)	51% (n = 24)	43% (n = 23)

Interestingly, a number of students noted that their preference would be to study STEM-related subjects in Welsh at A-level, either exclusively or alongside English (74%-86% of respondents).

While there were no significant differences between the pupils' gender and the language that they would choose if they were to study these subjects at A-level, pupils who came from English-medium homes were more likely to choose to study these subjects in English, while the pupils from Welsh-medium homes showed a preference towards studying them in Welsh.

3.2 Choosing STEM-related subjects at University

Pupils were asked how likely they would be to consider choosing the traditional STEM-related subjects or a combination of those subjects at university. The responses are noted in Table 5 below:

Table 5: The likelihood of pupils opting to study a STEM-related subject, or combination of those subjects, at University

	Very unlikely	Quite unlikely	Not sure	Quite likely	Very likely
Physics	49% (n = 33)	15% (n = 10)	18% (n = 12)	12% (n = 8)	7% (n = 5)
Biology	41% (n = 28)	13% (n = 9)	16% (n = 11)	16% (n = 11)	13% (n = 9)
Chemistry	49% (n = 33)	13% (n = 9)	18% (n = 12)	10% (n = 7)	10% (n = 7)
Design and Technology	50% (n = 34)	13% (n = 9)	24% (n = 16)	7% (n = 5)	6% (n = 4)
Computer Science	55% (n = 37)	12% (n = 8)	18% (n = 12)	9% (n = 6)	6% (n = 4)
Combined Sciences	51% (n = 34)	15% (n = 10)	15% (n = 10)	13% (n = 9)	6% (n = 4)
Combined Sciences & Technology	52% (n = 35)	21% (n = 14)	16% (n = 11)	9% (n = 6)	2% (n = 1)
Combined Technologies	55% (n = 37)	15% (n = 10)	18% (n = 12)	10% (n = 7)	2% (n = 1)
Maths	41% (n = 28)	12% (n = 8)	18% (n = 12)	16% (n = 11)	13% (n = 9)
Other (e.g. bio-chem, ocean sciences etc)	43% (n = 29)	13% (n = 9)	21% (n = 14)	9% (n = 6)	13% (n = 9)
Combined Sciences and Maths	54% (n = 37)	13% (n = 9)	15% (n = 10)	10% (n = 7)	7% (n = 5)
Combined Technologies and maths	60% (n = 40)	18% (n = 12)	13% (n = 9)	5% (n = 3)	5% (n = 3)

A further 22% (n = 15) of the pupils noted that they would consider studying other subjects. These included: Medicine (n = 3), Psychology (n = 1), Veterinary Sciences (n = 1), Biochemistry (n = 3), Marine Biology (n = 3) and Biomedical Sciences (n = 1).

As can be seen in Table 5, the number of students who would consider STEM-related degrees are relatively low. The most likely subjects, in line with the most popular subjects they chose at A-Level, were Biology and Maths (29% quite or very likely in each case).

Pupils were also asked whether they would prefer to study these subjects at university in Welsh, English or bilingually.

Table 6: Proportion responses to the linguistic choices pupils would make if studying these subjects at University

	Biology	Chemistry	Computing	Design & Technology	Physics	Maths
English	35% (n = 14)	34% (n = 11)	24% (n = 7)	15% (n = 4)	37% (n = 11)	38% (n = 15)
Bilingual	38% (n = 15)	44% (n = 14)	48% (n = 14)	54% (n = 14)	37% (n = 11)	33% (n = 13)
Welsh	28% (n = 11)	22% (n = 7)	28% (n = 8)	31% (n = 31)	27% (n = 8)	30% (n = 12)

Whilst pupils generally favoured studying these subjects *in Welsh* at A-level, a *bilingual* approach seemed to be the favoured choice at University for most subjects. Again, the trend shows that pupils that come from English-speaking homes were more likely to opt to study these subjects at university in English while the pupils from Welsh-medium homes were more likely to opt for the Welsh-language option.

3.3 Career choices

When the pupils were asked whether they had considered pursuing a career in which Science, Technology and/or Mathematics was central, 36% (n =26) stated that they had considered this while 21% (n = 15) stated that they had not. The remaining 44% (n = 32) stated that they were unsure. Of those who had noted that they had an interest in pursuing such a career the examples provided included doctor (n = 7), vet (n = 2), nurse (n = 4),

surgeon (n = 1), physiotherapist (n = 2), medical research (n = 1), computer scientist (n = 1), engineering (n = 2), forensic psychologist (n = 1), psychologist (n = 1), pathologist (n = 1), zoologist (n = 1) and marine biologist (n = 1).

Pupils were asked whether being able to discuss these subjects in Welsh would be useful for those careers. Fifty one percent (n = 30) either strongly agreed or agreed somewhat that being able to discuss these subjects in Welsh would be useful, while 29% (n = 17) of the pupils were unsure of its usefulness and 21% (n = 12) questioning its usefulness.

In addition to their consideration of a STEM-related career, the questionnaire also enquired whether they had any desire to become teachers. 37% (n = 26) of the pupils noted that they had considered a career in teaching, although only 31% (n = 8) of those had considered teaching a STEM subject. Unsurprisingly, given the higher numbers of females who tend to apply for teaching courses, female pupils were much more likely to consider a career in teaching (44%, n = 25) compared to the male pupils (8%, n = 1) (χ^2 (1, n = 70) = 5.931, $p < .05$) (although recall that there were any more female respondents than male respondents within the sample).

Many pupils (41%, n=28) believed that an individual's chance of obtaining a job as a STEM teacher would be higher if they were able to teach in Welsh, with a further 48% (n = 33) unsure. Much of the reasoning behind this response focused on the fact that Welsh is compulsory in some contexts and the medium of delivery, in which case knowledge of Welsh would be essential. Only 12% (n = 8) did not believe that the chance of obtaining a STEM teaching job would be higher if a person could speak Welsh.

3.4 Attitudes towards Welsh-medium STEM education

In order to explore why the uptake of STEM subjects tends to be low, and many opt to study these subjects in English rather than in Welsh, pupils were asked to provide their opinion around a series of 17 statements that were linked to learning about STEM in school through the medium of Welsh.

Table 7: Attitudes towards Welsh-medium STEM education

	Strongly agree	Agree somewhat	No opinion	Disagree somewhat	Strongly disagree
Learning about Science, Technology and Mathematics subjects is fun A1	20% (n = 14)	32% (n = 23)	31% (n = 22)	7% (n = 5)	10% (n = 7)
It's a strange feeling to be learning about Science, Technology and Mathematics in Welsh A2	6% (n = 4)	20% (n = 14)	21% (n = 15)	21% (n = 15)	32% (n = 23)
It's easy to learn about Science, Technology and Mathematics in Welsh A3	23% (n = 16)	39% (n = 28)	13% (n = 9)	16% (n = 11)	10% (n = 7)
The English language is better suited to Science, Technology and Mathematical subjects than Welsh A4	16% (n = 11)	28% (n = 20)	34% (n = 24)	11% (n = 8)	11% (n = 8)
Being able to use Welsh for everything is important A5	43% (n = 30)	33% (n = 23)	11% (n = 8)	6% (n = 4)	7% (n = 5)
I don't care whether I learn about Science, Technology and Mathematics in Welsh or English A6	16% (n = 11)	22% (n = 16)	24% (n = 17)	18% (n = 13)	20% (n = 14)
I get confused when I learn about Science, Technology and Mathematics in Welsh A7	6% (n = 4)	29% (n = 20)	19% (n = 13)	26% (n = 18)	21% (n = 15)
I want to be able to learn about Science, Technology and Mathematics in both English and Welsh A8	28% (n = 20)	35% (n = 25)	24% (n = 17)	6% (n = 4)	7% (n = 5)
Things make more sense to me when I learn about them through the medium of Welsh A9	20% (n = 14)	27% (n = 19)	20% (n = 14)	21% (n = 15)	13% (n = 9)
I enjoy Science, Technology and Mathematics lessons because I'm able to learn about them through the medium of Welsh A10	9% (n = 6)	18% (n = 13)	38% (n = 27)	13% (n = 9)	23% (n = 16)
I understand Science, Technology and Mathematics subjects better when the content is explained to me in both English and Welsh A11	28% (n = 20)	27% (n = 19)	21% (n = 15)	14% (n = 10)	10% (n = 7)
I prefer to keep to the English when learning about Science, Technology and Mathematics A12	17% (n = 12)	17% (n = 12)	35% (n = 25)	10% (n = 7)	21% (n = 15)
I don't enjoy Science, Technology and Mathematics lessons A13	18% (n = 12)	16% (n = 11)	18% (n = 12)	19% (n = 13)	29% (n = 20)
I enjoy learning about things through the medium of Welsh A14	34% (n = 24)	37% (n = 26)	20% (n = 14)	6% (n = 4)	3% (n = 2)
It's important that I learn about Science, Technology and Mathematics in both Welsh and English so that I can then discuss them with my friends A15	25% (n = 17)	38% (n = 26)	19% (n = 13)	10% (n = 7)	7% (n = 5)
Learning about Science, Technology and Mathematics in both Welsh and English would be confusing A16	6% (n = 4)	17% (n = 12)	33% (n = 23)	26% (n = 18)	19% (n = 13)
Learning about Science, Technology and Mathematics in Welsh is ok, but we need to know the English terms in order to discover things on the internet etc A17	54% (n = 38)	26% (n = 18)	11% (n = 8)	3% (n = 2)	6% (n = 4)

Despite only around half of the pupils (52%, n = 37) noting that they thought that these subjects were fun, many more pupils (81%, n = 50) said that they enjoy learning about things through the medium of Welsh, which shows a more positive attitude towards the language than the subjects. When asked about their feelings towards using a certain language when studying these subjects, the results were mixed. When asked if things make more sense to them when they are explained in Welsh, 47% (n = 33) agreed and 34% (n = 25) disagreed. A similar pattern was observed when pupils were asked whether they cared if they learnt about the subjects in Welsh or English. Thirty eight percent (n = 27) agreed and disagreed with the statement. Pupils did, however, see the importance of English in the

contexts of these subjects, both in order to be able to discuss them with their friends (63%, n = 43) and to search for the terms on the internet (80%, n = 56).

Pupils were also asked whether they had any other suggestions as to how Universities could help address the shortage in Welsh-medium STEM-related subjects. Many of the responses referred to developing Welsh-medium resources:

> *They could invest on having extra online work provided in the language of Welsh.*
>
> *More study books for Science, Maths and Technology in Welsh to help the pupils*
>
> *Maybe provide simple books about the subjects in Welsh so that the pupils get used to reading about the subjects in Welsh*
>
> *Provide more Welsh resources e.g. revision guidance, websites with Welsh information, send teachers on Welsh courses, and employ teachers who can teach through Welsh*
>
> *Continue to create resources like the GCSE Science booklets that are available for teachers and pupils bilingually, and revision days too. But maybe make more of them and for different levels*
>
> *Provide/give us work (a year's/term's worth of work) to do on the subject which is useful for the pupils to continue with the work or do 'skype calls' once a week to provide leadership*

Other pupils believed that more could be done to promote these subjects:

> *Talk more about the good things*
>
> *Discuss it in school and display information so that we understand*
>
> *Advertise more on social media websites or go around schools to talk about it*

The remaining two pupils had different ideas. One simply noted *Offer them Welsh lessons,* although there was no indication as to whom this was targeted (pupils or teachers). The other pupil noted:

> *Decrease the number of credits that's needed to study to be eligible for bursaries, and offer more credits to study through Welsh*

4. Discussion

The main findings to emerge from the questionnaire to school pupils are summarised below:

First, there was a general acceptance among the pupils attending secondary schools in Wales that there is an English bias in science, echoing previous findings in the field (e.g., Berg et al., 2001; Ferguson et al., 2011; Sano, 2002). Within the Welsh-English bilingual context of Wales, this perception of an English bias does seem to feature quite heavily in Welsh pupils' linguistic choices and desires when considering studying STEM-related subjects, particularly at the latter stages of education.

Second, where Welsh-medium options are available for STEM-related subjects at school, many pupils – particularly those from Welsh-speaking backgrounds and/or those who have already followed most of their education through the medium of Welsh – are likely to continue to study STEM-related subjects in Welsh or bilingually, should they be interested in those subjects. These findings echo those of O'Hanlon (2015) who found that pupils often preferred studying through the medium of Welsh over studying through the medium of English. Whether or not the decision made by the pupils involved in the current study was a political one in the sense that pupils are exercising their right to education in their L1 is unclear from this study alone. Further study is needed to identify to what extent these decisions are informed by pupils' assumptions around the importance of mother tongue education. However, interestingly, speaking Welsh at home, either exclusively or alongside English, did not necessarily influence a given pupil's intent to study these subjects through the medium of Welsh or bilingually. Rather, and in addition to some of the factors identified by O'Hanlon (2015), some of the reasons behind these decisions were rooted more in their perceptions of their own linguistic abilities, their prior experiences with learning these subjects, and their willingness (or not) to learn new terminology and subject-specific information in another language. Individuals' perceptions of their own linguistic abilities and achievements when learning through a particular language are often linked to low self-esteem and anxiety around using the language, issues that often deter pupils from using or choosing to use a particular language (e.g., Cenoz et al., 2022). This is particularly the case where pupils are made to choose one language over another. The dilemma of language choice at school may lead pupils to make decisions that are focused around language per se rather than subject or learning based, decisions that may ultimately affect the learning process itself and impact on their educational achievement.

Third, of those pupils who opted to study STEM-related subjects bilingually at school, their reasonings related to the ability to use English to facilitate or to scaffold their access to the curriculum in Welsh (Costa et al., 2000; Hermans et al., 1998; Hoshino & Kroll, 1998; Tognini & Oliver, 2012), the flexibility of bilingual study, and the awareness of the need to be able to access the subject in English on top of Welsh, whilst also being able to use both languages later on in the workplace. That is to say that the ability to study bilingually or to be able to concurrently engage with STEM-related subjects in English and in Welsh seems to be a preference for some. These pupils were therefore strategic in their choices, with an eye on ensuring access to knowledge and options for future employment and study (cf. O'Hanlon, 2015).

Fourth, pupils from non-Welsh-speaking backgrounds tended to opt for English-medium study where the alternative was Welsh-medium study. This was largely due to the perceived progression opportunities in English, both for employment and further study, beyond school (Berg et al., 2001). However, where bilingual options were possible, this would also be a choice they would consider at school.

Fifth, unlike the trends reported by Welsh-speaking pupils making bilingual or Welsh-medium subject choices at school, at university, the majority of pupils, including those attending Welsh-medium schools, would opt to study these subjects bilingually. These findings reflect the general opinion that certain STEM-related subjects are more accessible in English (Ferguson et al., 2011; Hanauer & Englander, 2013; Lillis & Curry, 2010; 2013; Liu, 2017; Plo Alastrué & Pérez-Llantada, 2015) but that pupils are also aware of the importance of bilingual skills in the workplace. Again, this seem to be a strategic choice, and takes into consideration pupils' beliefs around the usefulness of Welsh vs. English within these subjects out in the workplace.

Finally, pupils from Welsh-speaking backgrounds tended to be less likely to study STEM-related subjects than those from non-Welsh-speaking backgrounds. Whilst this is an important finding that highlights a growing issue in terms of capacity building for Welsh-speaking STEM teachers in school, it highlights a potential demographic that may be underrepresented in STEM-related professions. What is not clear from the current study is whether or not the opportunity to study STEM-related subjects through the medium of Welsh (or the ability to include some Welsh whilst studying in English) was a positive factor in this trend, or whether pupils from Welsh-speaking backgrounds opted out of STEM-

related subjects due to their perceived inadequacies in their English (cf. Pronskikh, 2018). This is an avenue for future research.

5. Implications of the findings

There is a market among Welsh-speaking students for Welsh-medium provision in STEM-related subjects, should the option be available. However, uptake of the provision does hinge on pupils' perceptions of their language abilities, what they're used to at school, and their future career trajectories within the field. Ideally, what pupils need is to be able to access knowledge effectively, and be able to draw on their entire linguistic repertoire when discussing and learning about STEM-related subject. Currently, schools tend to offer Welsh-medium or English-medium options when studying STEM-related subject. Yet, Welsh-medium provision or English-medium provision in STEM-related subject does not need to be exclusively Welsh or English – translanguaging options could be explored within these subjects in order to draw more students to continue to study through the medium of Welsh whilst also benefitting from exposure to resources and equivalent terminology and scientific expression in English, and vice-versa (see, e.g., Pierson et al., 2021). Whilst the English bias for STEM-related subjects at the university level and later on in the workplace seems firmly rooted in pupils' perceptions, schools can do more to help prepare pupils for further study or employment in STEM-related subjects where the use of English or Welsh is required. Although STEM-related subjects among the population of this study were studied bilingually in some contexts, in the main, pupils tended to study STEM-related subjects either wholly in English or wholly in Welsh. However, in the Welsh-English context, being able to access knowledge in both languages was a clear consideration for students. Combining the languages in delivery using the concepts of pedagogical translanguaging would benefit students whilst allowing them to study predominantly in their preferred language, and help reduce linguistic anxieties (Cenoz et al., 2022). These opportunities to use and develop their bilingual skills would help pupils (i) develop appropriate terminology, in both languages, to be able to discuss the subject confidently in both Welsh and English with various types of audiences; (ii) learn how to write scientifically in the subject, both for academic and informal purposes, in both Welsh and English; and (iii) to be able to maximise their employability through engaging positively with their bilingualism. These same delivery methods should be considered at university level where opportunities to continue to study

STEM-related subjects are available in Welsh. Ultimately, however, more must be done to understand pupils' retention and engagement with STEM subjects (see, e.g., Sithole et al., 2017) in order to help increase pupils' interest in and enjoyment of STEM-related subjects before any strategies to support access to knowledge through Welsh, English or a combination of the two can be effectively developed.

However, one barrier that seems to influence linguistic choices is pupils' self-perception of their own linguistic abilities (cf. Thomas et al., 2012; Thomas et al., 2014) and the limitations they pose on their own opportunities to expand their knowledge cross-linguistically. Being within a 'comfort zone' is often preferred over being in a challenging context, but pupil assumptions around the complexities of using two sets of terminology or adding a new set of terminology to one that has already been established is clearly a moot point. What schools can do to alleviate pupil concerns around the learning of additional terminology is to ensure pupils are aware that terminology is always learned, that labels (terms) are learned in a piecemeal fashion, item by item, in English and in Welsh, and that some terms are more accessible or express meaning more directly in one language or another and can therefore help transfer and supplement knowledge from one language to the other. For example, *avalanche,* a French borrowing, for English speakers is not easily analysable into meaningful chunks due to its Latin roots. The Welsh *eirlithriad*, on the other hand, is easily analysable into *eir(a)* 'snow' and *llithro 'to slip*' and carries direct meaning for the pupil – snow that slips. Similarly for volcano. Whilst the constituent parts of the word carry little or no meaning for pupils, the Welsh *llosgfynydd* – *llosg* 'a burn' and *mynydd* 'mountain' does (cf. an example of a teacher explaining the term *percent* by comparing with the equivalent *canran* – *can* 'hundred' + *rhan* 'part' in Welsh, Jones & Lewis, 2014). Providing focused instruction on the learning of terms, within a wider context of subject-specific discourse, may help readjust pupils' feelings of inadequacy with the language per se and help develop bilingual subject knowledge whilst still receiving their education through their chosen language. Ultimately, this means becoming bilingual and biliterate in the 'languages of science and technology' in order that pupils can analyse, process and produce subject-specific narratives and concepts confidently in multiple languages.

Finally, in order to harness further pupils' awareness of the benefits of bilingual skills in the workplace, school and universities could do more to engage with employers and industry partners in order to identify where the benefits of speaking Welsh may lie.

Marketing the additional opportunities afforded to bilingual speakers out in the workplace could support school efforts to develop pupil interest in STEM-related subjects in order that they can then progress to study these subjects confidently, in Welsh and/or in English, and help grow capacity within the field.

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