The NUSTEM Approach: Tackling the Engineering and Gender Challenge Together from Early Years to Sixth Form and beyond

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Abstract - Despite significant investment in initiatives to increase participation and diversity in physical and computer sciences, technology and engineering, there has not been a corresponding increase in the number of young people choosing these subjects, and a strong gender imbalance remains. NUSTEM, a collaborative widening participation and outreach initiative at Northumbria University, believes a radical rethink is necessary to solve this engineering challenge. NUSTEM is investing in the next generation by working extensively with young people and their key influencers: parents, carers and teachers, from primary school to sixth form and beyond. Building on their own original research and experience combined with previous research and recommendation from others, NUSTEM has developed an innovative model of practice and theory of change. This paper identifies the evidence that has informed the development of the approach and outlines three key requirements for increasing the uptake of physical and computer sciences, technology and engineering by young people from under-represented groups.

I. INTRODUCTION

NUSTEM is a collaborative Science, Technology, Engineering and Mathematics (STEM) initiative based at Northumbria University, Newcastle, working in partnership with industry, science and education bodies and schools to increase diversity in the physical and computer sciences, engineering and technology sectors in the North East. NUSTEM works with young people from early years to sixth-form across five regional local authorities in the North East of England: Newcastle, North Tyneside, Gateshead, Durham and Northumberland.

A literature review of evidence in what works with STEM interventions, particularly for females and other under-represented groups, alongside original research, identified three important principles that NUSTEM have implemented in their theory of change. This paper reviews each of these principles in turn, and presents the supporting evidence behind their adoption. The three principles are:

- Engagement and activities should start early in a child's education and be sustained throughout.
- Engagement with a young person's key influencers is also vital: parents, carers, schools, teachers and the wider community.
- Engagement should highlight the utility and ubiquity of STEM and STEM careers and seek to raise awareness of unconscious biases and gender stereotyping.

II. EARLY AND SUSTAINED ENGAGEMENT

NUSTEM is guided by the principle that outreach activities that enthuse and inform young people from early years onwards, will encourage more young people to consider careers in engineering and other STEM areas.

Evidence shows that to generate significant impacts on participation at secondary school, engagements need to start in primary school [1] [2]. The decline in young people's attitudes to science from age 11 is well-documented and a number of research studies show that children's attitudes towards school science decline even in primary schools [3] [4]. Hadden and Johnstone's study reports no improvement in attitude towards science from the age of 9 [5]; an indication that children are becoming disengaged with science towards the end of primary school. Despite the decline in upper primary, overall children's attitudes to science within primary schools remains generally positive [6]. Primary school teachers are therefore in a good position to sustain interest in science through to upper

primary ages. To sustain primary children's positive attitudes to science, the Wellcome Trust recommends making primary science more relevant to children's everyday lives, and placing a greater focus on children's thinking, questioning and investigative skills [6].

Children also begin to form their occupational aspirations within primary school. At the age of 6 – 8 years, naïve early understandings turn them towards some possible futures and away from others [7]. Through ages 9-13 children further limit the number of possible occupations; for being for a different gender, the wrong level, or being beyond their capabilities [7]. Children rarely reintroduce occupations once they have been dismissed, and therefore primary schools can play a key role in supporting children to keep their options open across a range of careers. A number of studies have recommended that efforts to broaden young people's aspirations, particularly around STEM, should begin in primary school, finding that secondary school interventions and activities are 'too little, too late' [1] [2].

As well as early intervention, NUSTEM believes that regular, sustained engagements are crucial for success. The UK STEM Education Landscape review finds that, despite there being over 600 organisations involved in the STEM education landscape and significant investment into activities and interventions over four decades, "*there is little robust evidence of the long-term impact of informal science learning activities in the UK*" [8]. Many STEM engagements are one-off activities, rather than a series of activities, or sustained engagement over a long period of time. A more sustained programme of activity integrating careers awareness into the STEM curriculum is more likely to be effective [9] [10] [11].

III. BUILD UNDERSTANDING AND CONFIDENCE OF KEY INFLUENCERS

Teacher and parental lack of confidence in their STEM ability, can exert significant influence on children's aspirations and decision making. NUSTEM believes that engagement with children's key influencers to improve confidence is necessary to improve participation in STEM.

Since science became a core subject of the primary curriculum in 1989, there have been frequent concerns raised regarding primary school teachers' ability to teach science effectively [3] [12] [13]. Teachers must have a good understanding of science concepts and the science curriculum if they are to impart this knowledge to children effectively. A lack of knowledge, "*leads teachers to display a closed pedagogy where the presentation of unrelated facts takes precedence over conceptual understanding*" [13, p.33]. Palmer's research discovered that teachers who lack confidence in their own science abilities, are more likely to be critical of students and give up on students encountering difficulties more readily [14]. Additionally Jarvis *et al* found that without a firm understanding of science concepts beyond the science curriculum, teachers develop misconceptions that can interfere with children's understanding [4]. Only 3%- 5% of the UK's primary school teachers hold a science or mathematics degree, which means that many schools have no one with an undergraduate qualification in mathematics or science [15].

Evidence shows that high-quality training, guidance and resources can improve primary school teachers understanding and confidence [4] [6]. Palmer found that primary school teacher confidence could be improved through observation of good practice first hand, and then the opportunity to model good practice in the classroom [14]. Teachers who undertook professional development in science felt more confident to assess and set up practical work, explain scientific ideas and ensure all children are engaged in science learning [6]. NUSTEM have been supporting primary school teachers to develop their career, subject and pedagogical knowledge, and empower them to lead science within their schools through CPD in science teaching and scientific principles at a regular Primary Science Coordinators forum.

At secondary school level education, the concern lies not with the lack of understanding of science content, rather that many science teachers have a limited understanding of careers in science, or the range of careers that science qualifications give access to [2] [16]. Without knowledge of the

role of science in the wider world, teachers and careers advisors are unable to adequately prepare young people for future study or careers in science.

It is less certain, however, how secondary careers education can be improved. Osbourne and Dillion recommend that schools improve resources available to inform students of careers in science, particularly emphasising the role of science as a cultural and humanitarian activity so as to appeal to girls, as well as emphasising that science qualifications can act as a door opener to a wide range of potential careers [17]. The OFSTED report 'Going in the Right Direction' highlights the good practice of where classroom teachers embed careers information into the general science curriculum, using first-hand, industry related knowledge to inspire students about careers education [18]. In secondary schools, NUSTEM is supporting science teachers to embed careers information into science teaching, providing access to diverse examples of related careers and linking schools with local STEM industries and employers.

Lack of confidence in science is not just a problem among teachers. A recent IET survey found that many parents lack confidence in their science ability, with 83% of UK parents unable to answer basic school-level 'science' questions, and 61% of parents fearful of being asked difficult questions by their child [19]. Similarly, parents of older children are often unaware of the possible education routes and career paths that studying STEM can lead to [1].

Parental engagement is one route to improving the science confidence of parents. The association between parental involvement and educational achievement is now well established. However, further research is needed to establish which types of parental engagements are likely to be most effective [20]. Gutman and Akerman maintain that since aspirations are formed young, early engagement with parents, particularly those in disadvantaged areas, is key to developing parents' early aspirations for their children and children's early aspirations and attitudes [7]. A number of studies have examined the role of parental engagement on children's literacy and numeracy outcomes, but few studies have examined how parental engagement can improve science outcomes, or the confidence of parents [21].

NUSTEM supports parents to more involved in their child's science education, and more confident in talking to their children about science. This involvement occurs through workshops, take-home activities, online, as well as five-week family learning courses 'Science for Families' and 'Engineering for Families'. These are successful in encouraging families to talk more about STEM at home. Additionally NUSTEM provides CPD in science parental engagement to schools.

IV. DRIVE FOR WIDER SOCIAL CHANGE

NUSTEM recognises that STEM interventions can only go so far in supporting children and young people to choose a future in STEM. Young people's aspirations and decision-making processes are shaped by their perception of themselves and their abilities, as well as their environment and social sphere, not just their interest and enjoyment of subjects and their experiences in the classroom [22]. Females' educational and occupational choices may be further restricted by gender role stereotypes and gendered attitudes.

Assumptions about the differences between females and males permeate modern life, culture and education [23]. Historically the differences between the genders were thought to be determined by biological factors, however the dominant discourse today is that gender is socially and culturally constructed through our interactions in society. Children's understanding of what it means to be male or female, are therefore determined by their experiences and interactions in their daily lives [24]. Research shows that children begin to follow gender stereotypes from before the age of five, and are often enthusiastic enforcers of gender conformity [25].

Stereotyping is universal, unconscious, and an unavoidable function of our brains, which enables us to think and act with speed and efficiency [26]. However, it can also have negative, unintended consequences. Research has shown that teachers commonly under-rate the academic ability of low-income pupils, non-white pupils, pupils with English as an Additional Language. Teachers also commonly under-rate the performance of male pupils in English and female pupils in Mathematics [26]. Sadker & Zittleman found that on average, teachers give males more time than females to answer questions in class, with white males receiving the most attention from teachers [27].

While impact of stereotyping on an individual particular outcome may be small, the effect of multiple stereotypes over time in different contexts, results in substantially different outcomes for children, of otherwise similar backgrounds or abilities [28]. Boys are twice as likely to study Mathematics, three times as likely to study Further Mathematics and more than four times as likely to take A-levels in Physics, while females are twice as likely to study English compared to boys [29]. Bian *et al*, found that from as early as 6 years old, females are less likely than males to believe that people of their gender are 'really, really smart', and that a significantly higher proportion of females begin to avoid activities said to be for 'really, really smart' children, compared to males [30].

Unless unconscious biases are addressed, they may continue to play a part in creating and perpetuating existing inequalities in society. It is important that anyone working in STEM education and engagement is reflexively aware of the ways that unconscious biases and gendered ideas influence practice and behaviour, and serve to constrain the learning experiences of children and young people [26] [31].

Unconscious bias and gender norming are societal issues that cannot be solved by the education system alone. However, teachers and educators in informal STEM learning remain in a strong position to promote equality through their practices. Earp highlights how teachers can with time and reflexive effort, can 'train' themselves to tame the stereotyping mechanism, by presuming motivation and ability in all students, drawing on alternative stereotypes of pupils, and being consciously balanced and constructive in interactions with and feedback to pupils [31]. The IOP's Closing Doors report found that the majority of schools fail to encourage subject choices in a gender neutral way, and that attempts to increase the number of females taking A-Level Physics would require changes to the whole-school culture not just the physics classroom [32]. The IOP's 'Improving Gender Balance' reports success with a whole school campaign on gender stereotyping. The programme influenced teachers to change the style and content of their teaching, to self-reflect more in regard to gender neutrality, to use more gender-neutral language within the classroom, and more diversity within careers examples [33].

NUSTEM is delivering Unconscious Bias Continuing Professional Development to teachers, education practitioners, academics, employers and industry across the North East and beyond. These sessions raise awareness of gendered language and common gendered behaviours, and ask participants to consider these in their engagements with children and young people. In schools, NUSTEM delivers CPD to staff across a whole school or department rather than just to science teachers, and provides additional support to schools to review their equality and diversity strategy and approach. Additionally NUSTEM works with industry and employers to review their education programmes and develop new practice that will help reduce unconscious biases in engagement work. By teaching this topic as part of the syllabus for Northumbria University Trainee Teachers, NUSTEM are raising awareness of unconscious bias among the next generation of teachers and offering them the tools to challenge biases within their teaching practice.

V. CONCLUSION

Lack of diversity in physical and computer sciences, technology, and engineering continues to be an issue despite over four decades of activity aimed at increasing diversity in these fields. NUSTEM have identified a need for universities and companies, and those delivering STEM engagements to adapt their approach and their target groups for their engagements. There is a real need to work with primary school children and their key influences, as engagements with secondary pupils are often too late to have the needed impact. Curriculum-related and careers inspired activities highlight the relevance of and possibilities within STEM, while regular and sustained engagements ensure there is support throughout a child's formative years. Wider societal issues are beginning to be addressed through an awareness of unconscious bias and the development of structures and processes to minimise the effect of bias, but there still much work that can be done in this area.

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