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Using E-Textiles to Challenge Gender Perceptions in STEM, Design and Career Aspirations of Secondary School Students

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ABSTRACT STEM subjects in the secondary school curriculum are largely the domain of boys, and the creative arts subjects are predominantly the territory of girls. This disparity permeates into higher education and leads to a gender imbalance in the workforce. This paper investigates issues of gender bias in the secondary school curriculum and explores student perceptions and self-efficacy for future academic success. Using the medium of electronic textiles (e-textiles) the research considers if multidisciplinary and co-design approaches to teaching could create a more gender-equitable environment, bring about a mindset shift in students' gender perceptions, and alter their perspectives for future university choices. A mixed-gender group of 32 secondary school students from different subject disciplines across science, technology and art and design took part in a year-long study. They were given opportunities to work

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on a co-design project which sought to break down barriers between subject disciplines and challenge stereotypical perceptions of the “type” and gender of student in each discipline. Students were introduced to an e-textiles project called “ElectroTex” which sought to challenge the current hidden-gendered curriculum. It drew upon curriculum topics from physics, computing, technology and art and design. The research was underpinned by overlapping frameworks of Social Cognitive Theory and Value Expectancy Theory. A mixed methodology approach comprising Action Research and Co-design was sandwiched between pre- and post-project questionnaires which determined how students’ perceptions had altered as a result of the project. The experiential learning demonstrated that students were able to connect science with design and harness the value of their collaborative knowledge by applying it to real life situations. The outcomes show that a multidisciplinary approach to learning can re-frame students’ perspectives on gender in the curriculum, empower them to consider design and science in mutually beneficial contexts, and raise their aspirations for future success.

KEYWORDS: E-textiles, self efficacy, gender bias, STEM, multidisciplinary, value-expectancy

Introduction

There has been a waning in the uptake of arts-based subjects at secondary school level in the UK with numbers of student entries dropping by 37% at GCSE level and 30% at A-Level between 2010 and 2020 (OFQAL 2020). This has resulted in a decline in the number of students progressing to higher level education in the creative arts. Government strategy is to cut funds in creative arts subjects and focus investment on promoting science, technology, engineering and maths (STEM) subjects, with particular emphasis on encouraging female students to take up these subjects. Parents, teachers and students often presume that these career paths are more likely to result into predictable careers which attract high salaries (Tomasetto et al. 2015; Chen et al. 2022). However, the Creative Industries is an integral economic and cultural component of the UK nationally and across its regions. Technology has been transforming the Creative Industries over the past two decades (Bertola and Teunissen 2018) and its evolving digital practices and the emerging careers that it offers are not always understood by parents, teachers and students. Teachers have great influence in the future life choices of their students and this has particular criticality at secondary school level education. The traditional approach in both secondary and higher education settings is that teachers and lecturers are trained to become educators of “subject disciplines” rather than of “students”. The current approach does not offer students pathways to build inter-related knowledge and understanding or scaffold a broader perspective about self-identity. It overlooks opportunities to develop "multidisciplinary educators" who can teach students how to solve complex issues. Benchmarking students against how they perform in one subject does not capture how their performance, understanding or enjoyment might be improved if assessed across two or three subjects. As it stands, the subject-singularity approach to learning and assessment often directs them down narrow pathways at university of either science, or arts and ultimately influences future career choices. This may limit their exposure to the complexity of real-world situations which do not always fit neatly into discipline-specific subjects. Contemporary societal problems often require innovative methods which embrace science, design and technology. Technology is advancing at a rapid pace, permeating through all aspects of modern life. It requires creative thinking and multifaceted approaches to harness the opportunities that it presents. The world that today's young people will graduate into will require them to maximize both their creative intellect and their scientific knowledge to make meaningful contributions to society. The legacy of gender-labelling of subjects still disproportionally affects uptake of STEM and creative subjects in schools and universities. Finding opportunities to neutralise gender perceptions in the classroom could be the key to encouraging a more balanced profile of students across subjects. Electronic textiles (e-textiles) offers a common ground for both boys and girls to explore science, technology and design in a non-gendered context. E-textiles brings these fields together by combining coding, crafting and circuitry (Kafai et al. 2013). It blends traditionally gendered practices of soft materials with hard electronic components. E-textiles has the potential to span science, technology and creativity and break down gender barriers. This could enhance pathways for girls to enter technology-led careers which are traditionally male dominated, and boys to pursue creative careers more associated with females such as textiles and fashion. The collaborative and borrowing nature of practice associated with e-textiles moves beyond a single-subject approach and exposes students to new ways of learning. It offers novel ways to re-think teaching strategies in multidisciplinary contexts which encourage understanding of real-world situations. This opens opportunities for students to change their perceptions about subjects they do not favour.

Gender Imbalance in Art and Design, and STEM Subject Choices

There is a decline in the number of students across both genders choosing to study Art to GCE (A-level), and the number of girls taking technology subjects to A-level is also diminishing. The knock-on effect eventually leads to an imbalance in the workforce. A recent government report "Applying Behavioural Insights to increase female students' uptake of STEM subjects at A Level" (Department of Education 2020) investigated female students engagement with career choices related to STEM and pursuing technology-led careers. It found that although girls outperform boys in STEM subjects at GCSE they are less likely to continue these subjects to A-Level. In 2021 93% of A-Level Art and Design students in the UK were girls, and 85% of computing students were boys; (Women in Science and Engineering 2021). Evidence from 2021 A-level results show that girls who took STEM subjects were outperforming boys. However the lower pattern of uptake by girls remains unchanged, and only 8% of females progress to a level 4+ STEM qualification (WISE 2021). Figure 1a and b extracted from recent JCQ data (JCQ 2021; JCQ 2020) depict the gender profile of GCSE and A-Level students in the UK. Table 1 shows relevant data extracted from Figure 1a and b and compares the changes across Design and STEM subjects between GCSE and A-Level in 2020 and the disparity is clearly highlighted. There is an almost two thirds gender divide (64%:36%) in favour of girls studying Art & Design at GCSE. However when Design is combined with Technology rather than Art the gender balance reverses significantly to 71%:29% in favour of boys. The gendered pattern continues into A-Level programmes. The data also illustrates that computing continues to remain largely the domain of boys.

Table 2 summarises relevant data extracted from the report "Statistics for the Provision of GCE A level Results 2017" (Carroll and Gill 2018) (which was the final time the statistics report was published for both GCSE and A-Level). It shows that the uptake of Textiles studied in the contexts of Art & Design (A&D:Tex), and Design & Technology (D&T:Tex) is very low with only 16% of girls at GCSE and

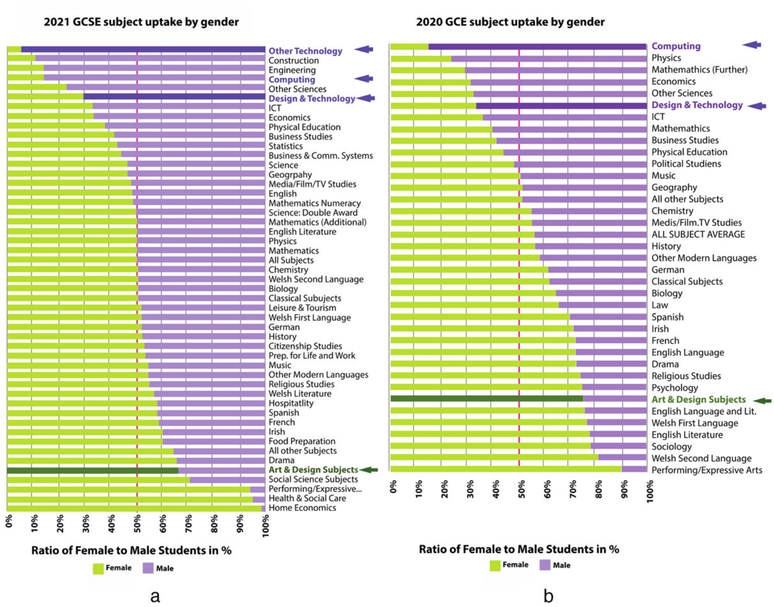

Figure 1

(a) Ratio of female to male uptake of GCSE extracted from JCQ data 2021.
(b) Ratio of female to male uptake of GCE extracted from JCQ data 2020.

Table 1. Summary highlighting gender divide in Art & Design and STEM subjects.

SUBJECT	2021 GCSE	GCSE	2020 GCE	GCE
	Girls	Boys	Girls	Boys
Art & Design	64%	36%	75%	25%
Design & Technology	29%	71%	35%	65%
Computing	21%	79%	14%	86%
Biology	51%	49%	64%	36%
Chemistry	50%	50%	53%	47%
Physics	50%	50%	22%	78%

Source: Extracted from JCQ data 2020 and JCQ data 2021.

Table 2. Percentages of student uptake of GCSE subjects in the UK between 2010 and 2017.

GCSE 2017	Boys	Girls	GCE 2017	Boys	Girls
Maths	85%	78%	Maths	39%	20%
Biology	67%	70%	Biology	17%	22%
Chemistry	67%	69%	Chemistry	18%	15%
Physics	67%	69%	Physics	20%	4%
Design & Technology: Electronics	14%	0.2%	Design & Technology	5%	2%
Design & Technology: Textiles	0.4%	39%		–	–
Art & Design	39%	47%	Art & Design	1%	3%
Art & Design: Textiles	0%	16%	Art & Design: Textiles	0.1%	2%

Data Source: Carroll and Gill 2018.

1.7% at GCE respectively choosing to opt for Textile specialisms. There were no boys at all choosing to study these subjects in 2017. The low numbers can partly be explained by analysing the number of schools offering these subjects. According to Carroll and Gill (Ibid) there were no single-sex boys schools in England offering A-level A&D:Tex or D&T:Tex. 8.5% of girls-only schools offered D&T:Tex and 7.9% of co-ed schools offered D&T:Tex. These statistics illustrate the lower priority given to creative subjects such as Textiles in schools. These findings are consistent with other studies, for example a recent systematic review of Irish school leavers (Delaney and Devereux 2019) using data from the Central Admissions Office (CAO) 2015 to 2017, found that there is a small gender gap across sciences and a considerably larger gap in engineering, and technology, attributable to students' subject choices. The gendered picture remains similar across grammar and comprehensive schools, and socio-economic divides.

Out of a possible 36 subject choices at A level, Art & Design ranks 24th for girls and 35th for boys. A&D: Tex. ranks 28th choice for girls and at 0.1% it ranks as the lowest A-Level option for boys at 36th place. There are a number of possible explanations for this very low uptake. Some students perceive that the current approach to teaching Textiles in schools does not enthuse students or allow for individual creativity (Bramley et al. 2015; Carroll and Gill 2018). Textiles is not always viewed by students or their parents as an academic subject (Abrahams 2018), and gender perceptions often mean that it is viewed as a "feminine" subject (Bell et al. 2013); (Solomka 2019). How D&T: Tex as a subject is taught in schools leads to predictable and standardised outcomes. Restrictive briefs and a lack of opportunity for creativity (Kimbell 2011) with the emphasis on output can also make it less appealing to study (Solomka ibid).

Legacy Effects of Stereotyping

Stereotyping by gender is still prevalent in society and academic domains today and this is well evidenced in research literature (Muntoni and Retelsdorf 2018; Raabe et al. 2019; Delaney and Devereux 2019; Jacob et al. 2020). Reviewing historical educational opportunities for women is helpful in understanding the legacy of perception which still suggests that "Textiles and Fashion", is a subject primarily for girls. Historically, the education of women was reserved for the privileged few and in the seventeenth century, females were singularly educated in the arts to limit their social empowerment (Ford 2010). Their roles have been confined to domestic contexts throughout history (Bain 2016) and inextricably linked with the production and maintenance of textiles in household and direct labour environments. Seventeenth century philosopher Francis Bacon proposed theories which connected male gender to science and female gender to nature and his ideas brought about a widespread dualism in thinking. The long-established legacy with science as a male domain (Lindner et al. 2022) and labelling around "masculinity" leads children from a young age to perceive that "science is for boys" (Tan et al. 2013; Archer et al. 2013). Some research suggests that the legacy from this type of thinking leads teachers to stereotype students in a manner that disadvantages girls (Tiedemann 2000; Carlana 2019). Their bias can be conscious or unconscious, however their perceptions are significantly influential in how children form beliefs in their own abilities (Tatar and Emmanuel 2001; Frawley 2005), with girls as young as 6 years old self-stereotyping as "poor at maths and science" (Tomasetto et al. 2015). By the age of 10 years old some children begin to label themselves as "not-STEM" and between the ages of 10 to 14 years considering future STEM-related careers are not always popular aspirations for girls (McDonald 2019). Teachers who stereotype these young students often have lower expectations of them. This can result in teachers developing curriculum material, adopting behaviours, segregating genders and providing feedback in a manner which collectively reinforces students' perceptions around gender (Frawley 2005). This can dispirit students who only become motivated to engage and achieve in learning activities that they believe fit with their gender (Brickhouse et al. 2000) and so this becomes a self-fulfilling prophecy. The gender bias and stereotyping is evident in tertiary level education where the climate of science and engineering departments in further education colleges and universities act as inhibitors to female progress in STEM fields (Buechley and Hill 2010). Females are less likely to enter traditionally male-dominated fields because of their "perception" that they have less ability and less interest in STEM-based subjects, despite statistics showing that their perceptions are without foundation (Blažev et al. 2017). The most cited reason for girls not pursuing STEM subjects to A-Level and on to university is low self-confidence. This can be explained by Social Cognitive Theory (Bussey and Bandura 1999). Its key construct is that people learn through observing others and emulate those behaviours. This becomes their process of regulating behaviour and their perceived self-efficacy, which in turn influences their outcome expectancies. Self-efficacy in a student learning context refers to the personal judgements that students make with regard to their ability and competence to take a course of action which will result in them attaining their academic goals (Bussey and Bandura 1999). How students perceive their learning environment also influences their personal judgements around their own ability. Self-belief in their capabilities to moderate their own learning is paramount in the learning process and has a bearing on both their motivation to learn and academic achievement. If girls are more confident about their abilities and have higher expectations for their success in non-STEM subjects they will naturally migrate towards those subjects (Chachashvili-Bolotin et al. 2016), irrespective of their actual ability in STEM subjects. A body of corroborative evidence agrees that students who have a strongly held belief regarding their ability to achieve academically are indeed more likely to achieve than students who do not have strong beliefs in their academic ability (Hackett et al. 1992; Van Dinther et al. 2011; Alt 2015; Gasiewski et al. 2012). Academic self-efficacy correlates to resilience and achievement in university (Robbins et al. 2004). This self-efficacy mindset can also negatively impact upon girls who have opted to study a creative career by choice for example Textiles and Fashion by making them feel like they are settling for a pathway with less credibility which can impact upon their self-esteem. Whilst most of the research focuses on gender bias in STEM subjects affecting girls, there is very little research on gender bias of boys selecting art and design subjects in so-called "female domains". Higher Education Statistics Agency (HESA 2020) figures on what subjects HE students enrolled for in 2019 show the ratio of girls to boys studying across all creative arts and design is 66:34. HESA do not readily make available any data on the number of boys choosing to study textiles or fashion. However anecdotal evidence from course leaders of fashion and textile courses and HESA statistics on gender breakdown in Textiles and Fashion degrees across the UK contained in The Uni Guide website suggest that the ratio is closer to 90:10 in favour of girls.

Addressing the Issues

Most of the research studies are concerned with identifying reasons why females do not go on to take up STEM careers and evidence suggests that the legacy of perceived societal norms either consciously or sub-consciously guide girls down career paths labelled as being "feminine" (Gudyanga et al. 2019; Measor 2020) such as Textiles and Fashion. However Textiles and Fashion has evolved over the past decade and these disciplines have embraced technology, science and engineering and embedded these into their practices. Some designers for example have explored electroconductive textiles for wider societal application such as mental wellbeing (Coulter et al. 2022) or healthy ageing (Yang et al. 2019). Bio-textiles is an emerging field which draws upon the alchemy of chemistry to create sustainable materials and challenge the fashion and textile industries to re-think their practices around sustainability (Mihaleva 2021). Novel examples include creating bio-materials from food waste (Provin and de Aguiar Dutra 2021). Developments in related fields such as engineering have enabled designers to develop novel outputs in laser cut fashion (El-Fanagely 2022) and 3D printed fashion (Dip et al. 2020). To date there are no research studies to show that students or teachers at secondary level understand how these technological developments have influenced textiles and fashion industries, or how a greater understanding of the changing face of these industries might impact future career choices for both boys and girls. Re-framing textile and fashion design as a subject which embraces STEM in a non-gendered context and with real-world applicability may cut through some long-standing perceptions. This would present a more relevant and appealing subject in the curriculum. The ElectroTex project proposes two ways to understand and address current teacher and student perceptions.

Value Expectancy Theory of Motivation Achievement

Before considering how to alter perceptions about future aspirations it is useful to understand what makes boys and girls choose different career pathways. The Value-Expectancy theoretical framework scrutinises individuals' psychological and contextual factors, underlying gender differences and traits. It can be applied to student contexts to help explain their academic motivation and performance, which ultimately impacts upon their future career choice (Eccles 1994; Wigfield and Eccles 2000). Wigfield and Eccles (1994) contend that individuals' expectations, along with their values or beliefs will affect their subsequent behaviours. The Expectancy-Value Theory hypothesises that the choices that students make which lead to their achievement are correlated and determined by two factors (i) how much they value a particular task in terms of significance and enjoyment, and (ii) how confident they feel in their ability to succeed in that task. The two factors studied in relation to each other can be useful in predicting students' sustained interest in the task, and their academic achievement. This can be further influenced and affected by stereotypes, perceptions of others' values and past experiences. The theory is widely used as a research tool in the field of education. Key elements such as value, interest, perception and expectation for success (VIPE) influence students' decisions towards which subjects they choose to pursue beyond GCSE level (Christodoulou 2017).

Re-Framing Contexts and Approaches

Reframing STEM subjects with broader contexts could pique the interest of a wider cross-section of students who do not always envisage themselves as STEM students. Girls are more likely to be interested in STEM subjects and careers when they are framed in strong pro-social contexts (Kijima et al. 2021). The post-millennial generation of students born after 1996 and often referred to as "Generation Z" have an entrepreneurial mindset and are likely to challenge traditional social norms. Their interest in collaborative approaches and hands-on active engagement learning activities (Annie. E. Casey Foundation 2022) makes them receptive to new modes of learning. None of this thinking however sits with the current single-subject, siloed approaches to teaching in secondary schools. There is little known about how a student's grades might change if they were benchmarked across two subjects. Exposing students to more hybrid approaches may alter their perceptions and their achievement outcomes. The current educational curriculum tends to focus on "how to use" technology applications rather than "create" applications (Kafai et al. 2014). Developing learning opportunities for students to construct their own gender identities by drawing across disciplines could help to break down gender-labelling of subjects. Gender-free language often used by technology and maker communities such as hacker, tinkerer, co-designer, or co-engineer (Tanenbaum et al. 2013) is also helpful in re-framing student perceptions around gendered subjects. E-textiles emerged and developed through maker communities and offers potential to reconsider stereotypical perceptions across STEM and design. E-textiles utilises soft materials and threads with conductive properties and combines them with electronics and computing to challenge traditional conventions of making. It offers an accessible route into computing and the possibility to experience this through aesthetics and design. "Textiles" sit comfortably within a "maker culture" which attracts a diverse cross-section of people. It builds a community of practice and provides opportunities for playful interaction in a group setting where discoveries are made and applied in new contexts (Weibert et al. 2014). The maker culture offers gender-diverse learning platforms which enable the socio-technical identities of learners to flourish. Learners are exposed to opportunities which take them beyond traditional boundaries of learning. The medium of e-textiles opens a comfortable route for female students to engage with computing (Weibert et al 2014). The maker culture however, challenges traditional teaching conventions in schools (Honey and Kanter 2013) and is therefore not embraced in the curriculum. One way of addressing this is through extra-curricular pursuits and research shows that female students' levels of "interest" in STEM-related fields and their attitudes towards STEM can change positively as a result of their participation in after-school activities (Weber 2011). Students who perceive that they will become more "socially valued" as an outcome of participating in an extracurricular activity whether that be academic or social, are more likely to engage (Kort-Butler and Hagewen 2011). It is also beneficial for teachers to create informal opportunities to enhance students' skills through STEM-related subjects as these are likely to impact positively on students attitudes toward STEM (Mannion and Coldwell 2008; Hynes et al. 2011). However such specialist extra-curricular workshops are often part of a one-off event and unlikely to make any meaningful difference in changing perceptions. Intervention needs to be considered as a suite of activities delivered over a longer period of time to bring about any meaningful change in students' VIPEs. The ElectroTex project sought to draw perceptions evidenced through Value-Expectancy together with a longitudinal study which offered gender-neutral opportunities to learn across disciplines through e-textiles.

Methodology

A mixed methods approach to the research brought about an intervention in 4 stages over the course of one academic year to address the issues raised. The methodology is summarised in Figure 2. Stage one comprised collecting qualitative data from online questionnaires prior to the project commencement. Stage 2 was conducted using an Action Research-based approach (Swann 2002). At stage 3 research data was gathered through design-thinking workshops and a co-design hackathon. Stage 4 comprised a post-project questionnaire to gather quantitative and qualitative data to compare the impact of the project.

The pre-project questionnaire ascertained age and gender. It was adapted from a model presented by (Appianing and Van Eck 2015) based on the Expectancy-Value Theory (Wigfield and Eccles 2000), and existing research on females in STEM-related education. Hypotheses statements were constructed around value, interest, perception and expectation for success in the context of science, technology and design. These sought to establish students (i) attitudes to studying STEM and design subjects at school, (ii) attitudes to how their subject choices might affect higher education study preferences and (iii) future employment aspirations. A second questionnaire was fielded at the post- stage of the project to evaluate how the creative

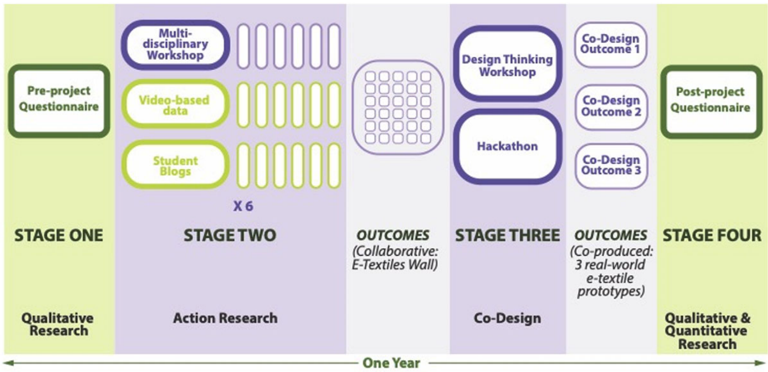

Figure 2
Mixed methodology framework.

approaches and multidisciplinary contexts altered students' perceptions to learning both STEM and creative subjects. Regular interactive workshops took place as voluntary extra-curricular activities. Students were encouraged to share knowledge and exchange skills across all areas of expertise. The data was captured through video footage taken at the workshops and student blogs written after each workshop. The Design-Thinking and 'Hackathon' events enabled the students to build upon their co-derived knowledge and contextualise their learning to co-produce outcomes which addressed social issues important to them.

The framework was underpinned by theories of Constructivism (Goldblatt 2006) and Participatory Action Research (PAR) (McTaggart 1991). Constructivist theory encourages learners to build their own meaningful knowledge through the process of self-questioning and reflecting upon their understanding. PAR enables collaboratively-generated scientific knowledge with social relevance (Reason and Bradbury 2001). Its collective and self-reflective nature of the practice improves students' understanding of how they learn in new social settings (McTaggart 1991). For PAR to be successful it is essential to design activities in ways that they have appeal and "hook" to ensure engagement. This in turn leads to a greater likelihood of innovative outcomes and new knowledge being produced.

Project Design

There were 32 students who participated in the project. The gender breakdown was 59% male and 41% female. The students identified themselves as follows:

The project was designed to create sufficient challenge and open-task approaches to encourage creative risk-taking by students and support learning in playful contexts. Playful learning (Forbes 2021) in educational settings has been shown to be a useful strategy in creating a safe environment for creative experimentation. The action research took place over the course of an academic year with

Subject	Girls	Boys
A&D	23%	0%
D&T	8%	21%
Computing	0%	36%
Science	67%	42%
Other	2%	1%

workshops and focus groups conducted over a 24-week period. A co-design approach was taken with male and female participants (both staff and students) drawn from Physics, Art & Design, and Technology subjects. All students in the host School between the ages of 14-18 were invited to a presentation by the author. After the presentation interested students were invited to submit an application to the School to participate in the research. 70 students applied and 35 students were selected by the School, with 32 of these students actually participating. The School ensured a gender, age and skills balance, and maintained student data protection. Full ethical approval was obtained from the University and from the School. Parental consent for student participation was also obtained prior to the project commencement. The students were introduced to electrical circuitry principles and demonstrations on how to create soft sensors, circuits and switches from textiles at masterclasses. These were supported by online tutorial material developed prior to the research which provided guidance on making different types of e-textile sensors and building a textile wall hanging. These were inspired and adapted from open-source material (Perner-Wilson and Buechley 2010). The tutorials were designed to be used independently and each task was achievable within the one-hour timeframe of an after-school club. They were placed into an open-access repository at the School so that the project could continue on a self-directed basis between workshops. This meant that School staff and students could avail of the knowledge and were free to contextualise and utilise it as they wished to support the curriculum and their own personal learning both during and after the project. This ensured that new knowledge was embedded within the School. All workshops were videoed, which enabled the author to capture students' interactions with the materials and with each other and reflect upon their "real time" views and perspectives. Monthly progress blogs were generated by the students to summarise cumulative progress made and these were published on the School's intranet, meaning that staff and students across the School had access to the learning from the project.

The results of the anonymous, online pre-project questionnaire determined the perceptions of the students prior to commencing the project. The questionnaire was repeated at the end of the project and included additional questions relating to views on learning in a multidisciplinary environment. This determined the experiences of the students and the impact on their learning of science and design as a result of the project. The staff also completed a short reflective, online questionnaire at the end of the project. Data gathered before, during and after the project through online and face-to-face interaction ensured that there was a rich source of both qualitative and quantitative data.

Observations and Outcomes

Students took ownership of the project very quickly. There were no assigned groups and students were free to integrate with each other as they wished. The relationships between the groups were formed organically and remained fluid as students needed to exchange knowledge on electrical circuitry, coding or design. It was noticeable from the outset that the Design & Technology students played a key role in forming a conduit between the groups and they appeared to be the most active in sharing knowledge with students and staff from other disciplines. At the end of Stage 2 of the research, the Design & Technology students took a lead in showing both staff and other students how the e-textile wall hanging could be programmed using an Adafruit Playground Circuit (Figure 3a and b). Figure 4 shows the work in progress.

Observations made from the video recordings showed that boys and girls engaged in the e-textiles activities with equal confidence. Boys were very keen to show that they could learn to stitch, although they chose to sit together and formed their own stitching group.

Design Thinking workshops were introduced at Stage 3 of the project. These gave students the opportunity to take co-ownership which enhanced their motivation, enthusiasm, communication and leadership skills. They provided a platform for ideas to be shared across disciplines and enabled students to collaborate and contribute their ideas on how e-textiles could be applied in real world contexts which were relevant to them. After brainstorming a range of ideas three final concepts were agreed upon to prototype. It was noted

a　　　　　　b

Figure 3

(a) Male and female student from different disciplines collaborating on assembling the textile wall. Image P.Cockbill. (b) Male Design & Technology student showing a female student and the Art & Design teacher how to programme an e-textiles circuit board. Image P.Cockbill.

Figure 4
Soft Sensor E-Textile Wall in progress. Image P.Cockbill.

that no fashion contexts were suggested by any of the students and the final ideas were gender-neutral. The ideas comprised:

- A school blazer pocket with a textile circuit breaker which could alert students if their phone was being pick pocketed
- Blazer pocket that illuminates at rural school bus stops to make drivers aware of passengers to pick up
- A soft musical keyboard

The latter idea came from a discussion between two students, where one had an interest in applying what he had learned to sound. He remarked to a fellow student that creating sound patterns through e-textiles could be really useful in engaging a family member with autism.

The outcomes of the Design Thinking Workshops were taken forward in a Hackathon, which is an open innovation event to encourage digital innovation (Briscoe 2014). Hackathons are typically fast-paced workshops conducted within a day or over the course of a weekend (Nandi and Mandernach 2016). New knowledge is acquired through peer engagement with participants learning from each other. They are usually team-based activities, where collective ideas are taken from inception and developed to a working software or hardware solution and showcased live to peers. The structure of a hackathon brings a playful element to learning and offers a fun and informal platform that enthuses students who are unmotivated in traditional classroom environments (Nandi and Mandernach 2016). The format offers a female-inclusive environment for learning (Paganini and Gama 2020) and can also be useful in more formal learning environments (Gama et al. 2018). The Hackathon took place in the School as an extended “after school into evening” event. The students self-selected their own groups which created an augmented synergy amongst them. Figure 5a shows the textile sensory keyboard that students created for engaging peers with autism. The shapes were based on the School crest and each soft sensor was programmed to a different musical note sound. The textiles were then connected in a matrix configuration to create the musical keyboard. Figure 5b shows a student completing the e-textile prototype of the circuit breaker pocket.

Questionnaire Results

The data in Figures 6 and 7 compares and contrasts male and female VIPEs across STEM and design-related subjects before the project. Briefly, the data revealed that both male and female students placed considerable value and importance on STEM subjects and comparatively little on textile design subjects. This stark contrast between STEM and design perspectives was echoed in students' aspirations for their future university choices. Data from boys suggested that only 10% saw design or textile design as a future career option and perceived that academically less capable students chose to study design. Students across both genders expressed confidence in their ability to undertake studies in STEM. This was not reflected in their self-assurance about design subjects. Surprisingly, a significant percentage of both male and female students perceived that they would enjoy working in STEM careers, with considerably less believing that they would enjoy a career in design. There was also a perception across genders, but particularly boys that jobs in textiles and design are generally not well paid and that STEM jobs command higher pay than design jobs. However, both boys and girls appeared to lack understanding of what textiles courses and careers entail. 55% of girls thought textile jobs required no STEM input and 59% of boys believed that there were no STEM elements in textile courses or jobs.

Prior to the project 62% of girls and 42% of boys thought STEM subjects are taught in a "boring" way in school. Almost half of all students thought that experiments in STEM classes did not always

a b

Figure 5

(a) School crest musical keyboard.Image P.Cockbill. (b) Student showing laser cut school blazer pocket with a textile circuit breaker.Image P.Cockbill

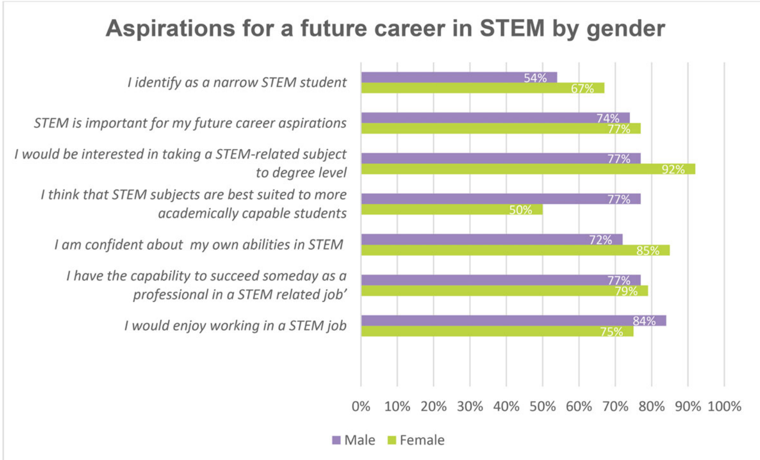

Figure 6
Aspirations for a future career in STEM by gender (pre-project).

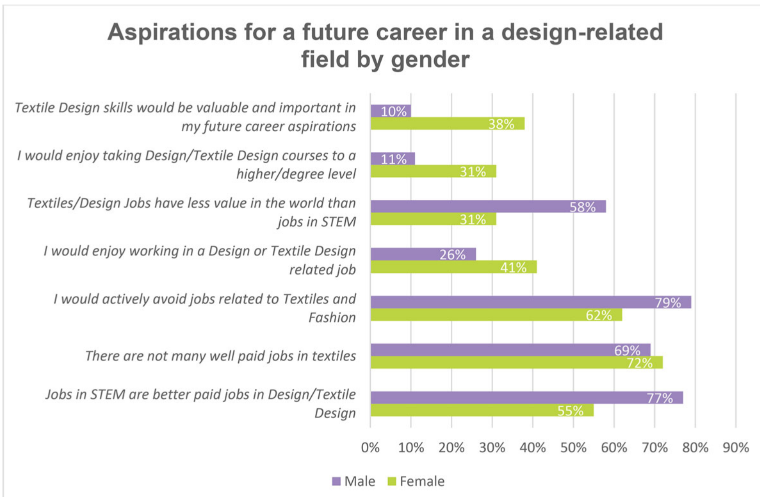

Figure 7
Aspirations for a future career in a design-related field by gender (Pre-project).

seem relevant to them and girls perceived the classes to be more tailored to boys. The ElectroTex project offered an alternative model to teaching STEM concepts in a more integrated and creative format. The post-project questionnaire compared students' experiences with perceptions before the project. Table 3 highlights the shift in gender perceptions about textiles and Figure 8 summarises the impact on student learning across multiple subject disciplines. These underscore the positive influence that the project made on students' VIPEs. By the end of the project 100% of the students reported that learning about electronics through e-textiles introduced a "fun" element to their learning. 56% of girls and 71% of boys reported that the

Table 3. Shift in gender perceptions about textiles after the project.

Hypothesis statement	Pre-Project	Post-Project	% difference
I would enjoy taking Design/Textile Design courses to a higher/degree level	19% (G 31% B 10%)	37% (G 50% B 29%)	18% ↑
I would enjoy working more with Textiles/Design projects in the future	25% (G 38% B 16%)	63% (G 75% B 57%)	38% ↑
I would rather do something else than take on a Textile/Design related job	72% (G 62% B 79%)	55% (G 50% B 57%)	17% ↓
Textiles is "easy" or a "soft option" subject	22% (G 23% B 21%)	9% (G 0% B 14%)	13% ↓

G = Girls
B = Boys

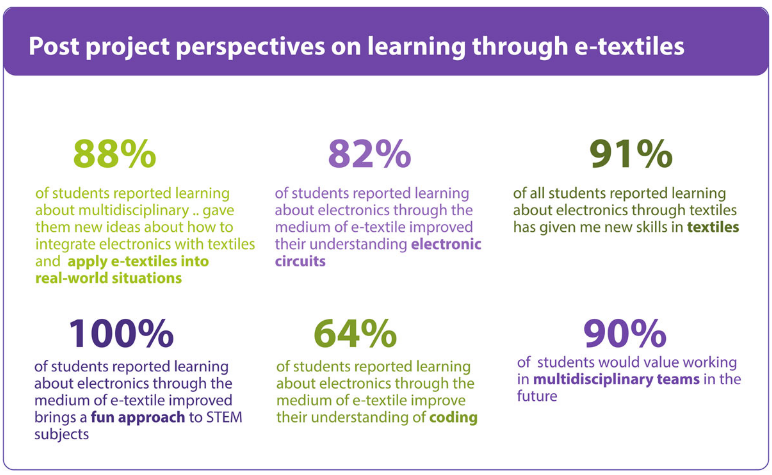

Figure 8
Post-project questionnaire outcomes of student.

project improved their coding skills. 86% of boys claimed that learning about electronics through the medium of textiles improved their understanding of circuitry, re-framed science in more creative contexts and gave them new skills in textiles.

The positive impact was illustrated in student narratives:

> I learnt a lot about different circuits and how they work through textiles and that they can be integrated into everyday items in interesting ways. (Girl)

> The greatest takeaway for me was learning and seeing how easily STEM and design can be combined to create amazing and useful outcomes. (Girl)

> The integrating of several different groups has helped develop my teamwork and communication skills as well as giving an insight to how a collaborative project works in industry. (Girl)

> Working with design students and e-textile materials helped me to think more creatively. (Boy)

> I learned to sew! Learning to integrate textiles and electronics sparked new ideas which I hadn't imagined before. (Boy)

> The project broadened my thought process as there are many soft materials I can use that can do similar jobs to electronic components. (Boy)

Staff reflections were collated based on a series of questions posed:

> What was your experience of multidisciplinary teams and working across departments?

> Very interesting - I would never have the opportunity to work with teachers from other departments so I have been surprised by the very different approach from the design side. It is remarkable to see how the pupils responded collaboratively to the brief.

> This was an excellent experience. The other teachers involved in the project were certainly ones I wouldn't have had the opportunity to collaborate with in the past. It was great to be involved in team teaching with other subject areas and have our eyes opened to new possibilities.

> Do you envisage any of the learning from the project being built into the Science curriculum, or the Art curriculum?

> Yes - I will introduce a more creative element into the Form 2 booklet on "Using Electricity" so that pupils will have a chance to combine a design element into designing circuits using some of the materials we have been using in the project.

> Absolutely! The textiles projects in the junior school could certainly incorporate electro textiles. Also, I think it is important to encourage our older "fashion" designers to think of design beyond visual aesthetics and have them consider functionalities.

> What worked well on the project?

> Having some student leaders who really helped to drive the project forward. Having a great balance of male/female,

junior/senior; science and design student really enhanced the project.

Were there any tangible benefits for you own CPD?

Absolutely! I have had the opportunity to new explore avenues with my existing set of skills and had the opportunity to learn new skills from both the other teachers and the students.

I understand more now about collaborative project management and this can bring about new and successful outcomes. I can see how I could organise projects like this in the future.

Discussion

The pre-project questionnaire results indicated that there is a lack of understanding amongst secondary school students of how technology has impacted and is continuing to re-define the textiles and fashion industry. The post-project questionnaire and the percentage shifts in thinking outlined in Table 3 revealed that the ElectroTex project had given students a more positive perspective around technology and STEM and encouraged them to view Textiles and Fashion design as a credible subject and career. Conducting the research over the period of a school-year provided a longitudinal opportunity to observe interaction between students of different genders and subject disciplines and how their behaviours and perceptions changed over time. The art students were very comfortable from the outset working with soft materials. Both boys and girls engaged in developing the textile sensors with equal confidence. There was a natural curiosity about conductive materials amongst all of the students. The science teachers seemed the most challenged by the organic nature of the workshops and retreated behind the teacher's desk or based themselves at the side benches along the walls of the classroom. Briefing the students at the outset that they had co-ownership of the project and that no one discipline contained all the knowledge to completing the project was imperative. Identifying that the success of the project would rely on shared knowledge inspired the students and gave them confidence to self-organise and collaborate. This enabled students to move fluidly between groups bridging digital and physical gaps in knowledge. Aesthetics were important to all the students. Given freedom to be creative some boys were excited to demonstrate that they already had sewing skills, others were eager to show they could learn sewing and embroidery stitches and were determined to show that they could produce aesthetically pleasing outcomes. Girls displayed less confidence in programming the electronics but were either keen to learn or to observe closely and some boys were very at ease sharing their knowledge with girls and teachers. Students negotiated their collaborations by assigning roles to each other within their own comfort zones - "I will sew the soft switch, if you figure out the circuit". Some students were keen to pitch in without much pre-planning, asking fellow students for help on an ad-hoc basis. Others planned the circuits carefully on paper to develop technical aspects and checked these with the physics students before trying to develop their circuit aesthetically. A few students took on leadership roles and teachers had the opportunity to listen and learn from different disciplines. The narratives from the questionnaires confirmed the broader student learning experiences through working with e-textiles. The project enabled students to observe other styles of learning, establish their preferred style of learning and to find new ways of supporting their own knowledge building through collaboration.

There were limitations to the project. The research took place within one school and repeating the project across a number of schools, may impact upon the data and give a broader range of perspectives. The project was developed as an "after schools club" which limited the time spent on the project each month. The sessions had to be organised into activities and tasks that could be completed and tidied up within one hour and often the success of the "tinker and try" approach adopted by e-textile communities tends to evolve ideas and share practice over longer time frames. However, the research was successful in bringing a greater understanding of students' perspectives on gender in the curriculum and their values, interest perceptions and expectations for future success. It further highlighted the enhanced learning benefits for both staff and students brought about by creative and multidisciplinarity approaches. Students acquired new knowledge, shared their existing knowledge and extended combined knowledge in unexpected ways. This enabled them to synthesise and contextualise know-how and apply it to real life situations that were important to them. The creative learning approach developed students' socio-cognitive abilities. The "tinker and try" approach enabled the students to gain a sense of achievement alongside enjoyment which enriched their learning experience. The playful pedagogies were in contrast to more didactic teacher-directed pedagogies that the students may have been more familiar with. This approach removed barriers to learning, positively affected student motivation and promoted engaged learning (Forbes 2021). Moderated risk-taking supported opportunities for the students to learn from failure (Whitton and Langan 2018). They were intrinsically motivated to engage with learning activities, knowing that failure was a possible and acceptable learning outcome. This happened throughout the project as conductive thread ends came loose and some crossed over each other causing the soft circuits to short out, or when the circuit polarity was stitched incorrectly.

The outcomes from the design-thinking workshops and hackathon showed that students degenderised their thinking, perhaps because of the mix of genders and disciplines in the group. Students had the freedom to make decisions about creating solutions which were relevant to them. Interestingly none of their e-textile outcomes from the design thinking workshop were aimed at a specific gender or fashion outcome.

The students had considered aesthetics in their outcomes through use of colour, decorative stitching, layering, personalisation through laser cutting and it appeared that these ideas were contributed equally amongst the boys and girls. New student perspectives emerged across both design and science disciplines. It was not so much that these had shifted away from STEM to design, rather the students' views on STEM remained constant but their perceptions around Textiles and Fashion had been positively influenced. The project highlights the value of creating central repositories of knowledge and "Open Source" materials in schools. These can be added to and accessed across all subjects in the curriculum to highlight synergies and encourage development of hybrid knowledge across science, design and technology. The project advocates the wider benefits of introducing more multidisciplinary teaching opportunities between science and design in schools. It demonstrates that collaborating across STEM and design subjects can bring about non-binary approaches which lead to new discovery and enable students to create new non-gendered identities. Further it offers a model to develop hybrid students with capabilities to problem solve in universities and the workplace. The outcomes from ElectroTex leave a platform for other researchers to further explore the role of design in creating multidisciplinary learning opportunities. By building on this work, other researchers may add to the body of evidence which will demonstrate to secondary school teachers, students and their parents the potential of textiles and fashion as a credible career choice. This may incentive curriculum planners in secondary and tertiary education to rethink how textiles and fashion courses can be re-imagined in gender-neutral contexts with content that is more inclusive of STEM and attracts more gender-balanced cohorts. The success of this particular e-textiles project was recognised nationally for its contribution in breaking down students' gender perceptions towards STEM and Design subjects in the secondary education curriculum and raising students' aspirations for future career choices. It was awarded the Rolls Royce Science Prize (Employees Choice). This provided a global platform to advocate for greater emphasis on STEM and Technology in Textiles and Fashion subjects in schools and universities which is vital to ensure that the subject supports the needs of a twenty first century workplace.

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References

Abrahams, J. 2018. "Option Blocks that Block Options: Exploring Inequalities in GCSE and a Level Options in England," *British Journal of Sociology of Education*, *39* (8): 1143–1159.

Alt, D. 2015. "Assessing the Contribution of a Constructivist Learning Environment to Academic Self-efficacy in Higher Education," *Learning Environments Research*, *18* (1): 47–67.

Annie, E, Casey Foundation 2022. *Social Issues that matter to Generation Z.* Available online at: https://www.aecf.org/blog/generation-z-social-issues [accessed 3 November 2022].

Appianing, J. and Van Eck, R.N. 2015. "Gender Differences in College Students' Perceptions of Technology-Related jobs in Computer Science," *International Journal of Gender, Science and Technology*, *7* (1): 28–56.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. and Wong, B. 2013. "Not Girly, Not Sexy, not Glamorous': Primary School Girls' and Parents' constructions of Science Aspirations," *Pedagogy, Culture & Society*, *21* (1): 171–194.

Bain, J. 2016. "'Darn Right I'm a Feminist… Sew What?' The Politics of Contemporary Home Dressmaking: Sewing, Slow Fashion and Feminism." In *Women's Studies International Forum*, Vol. 54, pp. 57–66. Oxford: Pergamon Press.

Bell, D., Hughes, C., and Owen-Jackson, G. 2013. "The (Continuing) Gender Debate." In Anon (ed.) *Debates in Design and Technology Education*, pp. 171–183. London: Routledge.

Bertola, P. and Teunissen, J. 2018. "Fashion 4.0. Innovating Fashion Industry Through Digital Transformation," *Research Journal of Textile and Apparel*, 22 (4): 352–369.

Blažev, M., Karabegović, M., Burušić, J. and Selimbegović, L. 2017. "Predicting Gender-STEM Stereotyped Beliefs Among Boys and Girls from Prior School Achievement and Interest in STEM School Subjects," *Social Psychology of Education*, *20* (4): 831–847.

Bramley, T., Rodeiro, C. and Vitello, S. 2015. Gender differences in GCSE. Cambridge Assessment Research Report.

Brickhouse, N.W., Lowery, P. and Schultz, K. 2000. "What Kind of a Girl Does Science? The Construction of School Science Identities," *Journal of Research in Science Teaching*, *37* (5): 441–458.

Briscoe, G. 2014. *Digital Innovation: The Hackathon Phenomenon*. London: Creativeworks.

Buechley, L. and Hill, B.M. 2010. LilyPad in the Wild: How Hardware's Long Tail is Supporting New Engineering and Design Communities. In: *Proceedings of the 8th ACM conference on designing interactive systems.* ACM, pp. 199–207.

Bussey, K. and Bandura, A. 1999. "Social Cognitive Theory of Gender Development and Differentiation," *Psychological Review*, *106* (4), 676.

Carlana, M. 2019. "Implicit Stereotypes: Evidence from Teachers' Gender Bias," *The Quarterly Journal of Economics*, *134* (3): 1163–1224.

Carroll, M. and Gill, T. 2018. Uptake of GCSE Subjects 2017. In *Statistics Report Series No. 120.* Cambridge: Cambridge Assessment.

Chachashvili-Bolotin, S., Milner-Bolotin, M. and Lissitsa, S. 2016. "Examination of Factors Predicting Secondary Students' Interest in Tertiary STEM Education," *International Journal of Science Education*, *38* (3): 366–390.

Chen, Y., Chiu, S.W.K., Zhu, J. and So, W.W.M. 2022. "Maintaining Secondary School Students' STEM Career Aspirations: The Role of Perceived Parental Expectations, Self-efficacy, and Cultural capital," *International Journal of Science Education*, *44* (3): 434–462.

Christodoulou, A. 2017. "Engaging in and with Research to Improve STEM Education," *Research Papers in Education*, *32* (4): 535–537.

Coulter, J., Magee, J. and Nugent, C. 2022. "E-Textiles: A Soft Touch Barometer for Female Students to Self-Manage Their Stress," *Journal of Textile Design Research and Practice*, *10* (3): 243–273.

Delaney, J.M. and Devereux, P.J. 2019. "Understanding Gender Differences in STEM: Evidence from College Applications," *Economics of Education Review*, *72* : 219–238.

Department for Education, B.I.T. 2020. *Applying Behavioural Insights to Increase Female Students' Uptake of STEM Subjects at A Level*. ERIC. Available online at: https://files.eric.ed.gov/fulltext/ED612262.pdf

Dip, T.M., Emu, A.S., Nafiz, M.N.H., Kundu, P., Rakhi, H.R., Sayam, A., Akhtarujjman, M., Shoaib, M., Ahmed, M.S. and Ushno, S.T. 2020. "3D Printing Technology for Textiles and Fashion," *Textile Progress*, *52* (4): 167–260.

Eccles, J.S. 1994. "Understanding Women's Educational and Occupational Choices: Applying the Eccles et al. Model of Achievement-Related Choices," *Psychology of Women Quarterly*, *18* (4): 585–609.

El-Fanagely, B.R. 2022. "The role of Laser Cutting Technology in Enriching Aesthetic Values and Highlighting Artistic Formulas on Leather Fabrics," *International Design Journal*, *12* (5): 165–177.

Forbes, L.K. 2021. "The Process of Play in Learning in Higher Education: A Phenomenological Study," *Journal of Teaching and Learning*, *15* (1): 57–73.

Ford, L. 2010. *Women and Politics: The Pursuit of Equality*. Boston, MA: Cengage Learning.

Frawley, T. 2005. "Gender Bias in the Classroom: Current Controversies and Implications for Teachers," *Childhood Education*, *81* (4): 221.

Gama, K., Alencar Gonçalves, B. and Alessio, P. 2018. "Hackathons in the Formal Learning Process." In: Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education, pp. 248–253.

Gasiewski, J.A., Eagan, M.K., Garcia, G.A., Hurtado, S. and Chang, M.J. 2012. "From Gatekeeping to Engagement: A Multicontextual, Mixed Method Study of Student Academic Engagement in Introductory STEM Courses,"*Research in Higher Education*, *53* (2): 229–261.

Goldblatt, P. 2006. "How John Dewey's Theories Underpin Art and Art Education," *Education and Culture*, 17–34.

Gudyanga, A., Gora, J. and Moyo, L. 2019. "Factors Affecting the Participation of Rural Male Students in Two Vocational Subjects in Zimbabwe," *Cogent Education*, *6* (1): 1633126.

Hackett, G., Betz, N.E., Casas, J.M. and Rocha-Singh, I.A. 1992. "Gender, Ethnicity, and Social Cognitive Factors Predicting the Academic Achievement of Students in Engineering,"*Journal of Counseling Psychology*, *39* (4): 527.

HESA. 2020. "Higher Education Student Statistics: UK, 2018/19 – Subjects Studied." HESA. Available online at: https://www.hesa.ac.uk/news/16-01-2020/sb255-higher-education-student-statistics/subjects [accessed 26 June 2022].

Honey, M., and Kanter, D.E. 2013. "Design, Make, Play: Growing the Next Generation of Science Innovators." In Anon (ed.) *Design, Make, Play*, pp. 1–6. London and New York: Routledge.

Hynes, M., Portsmore, M., Dare, E., Milto, E., Rogers, C., Hammer, D. and Carberry, A. 2011. Infusing Engineering Design into High School STEM Courses.

Jacob, M., Iannelli, C., Duta, A. and Smyth, E. 2020. "Secondary School Subjects and Gendered STEM Enrolment in Higher education in Germany, Ireland, and Scotland," *International Journal of Comparative Sociology*, *61* (1): 59–78.

JCQ. 2021. *GCSE (Full Course)Results Summer 2021 for UK, England, Northern Ireland & Wales, including UK age breakdowns*. London: Joint Council of Publications. Available online at: https://www.jcq.org.uk/wp-content/uploads/2021/08/GCSE-Full-Course-Results-Summer-2021.pdf [accessed 24 June 2022].

JCQ. 2020. *GCE A Level & GCE* AS Level Results Summer *2020.* London: Joint Council for Qualifications. Available online at: https://www.jcq.org.uk/wp-content/uploads/2020/09/A-Level-and-AS-Results-Summer-2020.pdf [accessed 24 June 2022].

Kafai, Y., Peppler, K., Boler, M. and Ratto, M. 2013. "Rethinking Transparency in Critical Making with e-Textiles." *DIY Citizenship*. Cambridge, MA: MIT Press.

Kafai, Y., Fields, D. and Searle, K. 2014. "Electronic Textiles as Disruptive Designs: Supporting and Challenging Maker Activities in Schools," *Harvard Educational Review*, *84* (4): 532–556.

Kijima, R., Yang-Yoshihara, M. and Maekawa, M.S. 2021. "Using Design Thinking to Cultivate the Next Generation of Female STEAM Thinkers," *International Journal of STEM Education*, *8* (1): 1–15.

Kimbell, L. 2011. "Rethinking Design Thinking: Part I," *Design and Culture*, *3* (3): 285–306.

Kort-Butler, L.A. and Hagewen, K.J. 2011. "School-based Extracurricular Activity Involvement and Adolescent Self-esteem: A Growth-curve Analysis,"*Journal of Youth and Adolescence*, *40* (5): 568–581.

Lindner, J., Makarova, E., Bernhard, D. and Brovelli, D. 2022. "Toward Gender Equality in Education—Teachers' Beliefs about Gender and Math," *Education Sciences*, *12* (6): 373.

Mannion, K. and Coldwell, M.R. 2008. After-School Science and Engineering Clubs Evaluation.

McDonald, A. 2019. *"Not for people like me?" Under-represented groups in science, technology and engineering*. Quest House 38 Vicar Lane Bradford, BD1 5LD: https://www.wisecampaign.org.uk/. Available online at: http://edileaditandliveit.co.uk/wp-content/uploads/2019/05/not_for_people_like_me-full-report.pdf [accessed 26 June 2022].

McTaggart, R. 1991. "Principles for Participatory Action Research," *Adult Education Quarterly*, *41* (3): 168–187.

Measor, L. 2020. Gender and the Sciences: Pupils' Gender-Based Conceptions Of School Subjects. In Anon (ed.), *Life in School*, pp. 89–105. London: Routledge.

Mihaleva, G. 2021. "Bio Matter in Creative Practises for Fashion and Design," *AI & Society*, *36* (4): 1361–1365.

Muntoni, F. and Retelsdorf, J. 2018. "Gender-specific Teacher Expectations in Reading—The Role of Teachers' Gender Stereotypes," *Contemporary Educational Psychology*, *54*: 212–220.

Nandi A. and Mandernach M. 2016. Hackathons as an Informal Learning Platform. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, pp. 346–351.

OFQAL. 2020. *Results tables for GCSE, AS and A level results in England, 2020*. Available online at: https://www.gov.uk/government/publications/results-tables-for-gcse-as-and-a-level-results-in-england-2020 [accessed 24 June 2022].

Paganini L. and Gama K. 2020. Engaging Women's Participation in Hackathons: A Qualitative Study with Participants of a Female-focused Hackathon. In *International Conference on Game Jams, Hackathons and Game Creation Events 2020*, pp. 8–15.

Perner-Wilson, H. and Buechley, L. 2010. Making Textile Sensors from Scratch. In *Proceedings of the Fourth International Conference On Tangible, Embedded, and Embodied Interaction*, pp. 349–352.

Provin, A.P. and de Aguiar Dutra, A.R. 2021. "Circular Economy for Fashion Industry: Use of Waste from the Food Industry for the Production of Biotextiles," *Technological Forecasting and Social Change*, *169* : 120858.

Raabe, I.J., Boda, Z. and Stadtfeld, C. 2019. "The Social Pipeline: How Friend Influence and Peer Exposure widen the STEM Gender Gap," *Sociology of Education*, *92* (2): 105–123.

Reason, P. and Bradbury, H. 2001. *Handbook of Action Research: Participative Inquiry and Practice*. London: Sage.

Robbins, S.B., Lauver, K., Le, H., Davis, D., Langley, R. and Carlstrom, A. 2004. "Do Psychosocial and Study Skill Factors Predict College Outcomes? A Meta-analysis,"*Psychological Bulletin*, *130* (2): 261.

Solomka, O.M. 2019. Literature Review on Issues Surrounding GCSE Textiles Courses in English Secondary Schools.

Swann, C. 2002. “Action Research and the Practice of Design,” *Design Issues*, *18* (1): 49–61.
Tan, E., Calabrese Barton, A., Kang, H. and O’Neill, T. 2013. “Desiring a Career in STEM-Related fields: How Middle School Girls Articulate and Negotiate Identities-in-Practice in Science,” *Journal of Research in Science Teaching*, *50* (10): 1143–1179.
Tanenbaum, T.J., Williams, A.M., Desjardins, A. and Tanenbaum, K. 2013. Democratizing Technology: Pleasure, Utility and Expressiveness in DIY and Maker Practice. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 2603–2612.
Tatar, M. and Emmanuel, G. 2001. “Teachers’ Perceptions of Their Students’ Gender Roles,” *The Journal of Educational Research*, *94* (4): 215–224.
Tiedemann, J. 2000. “Parents’ Gender Stereotypes and Teachers’ Beliefs as Predictors of Children’s Concept of their Mathematical Ability in Elementary School,”*Journal of Educational Psychology*, *92* (1): 144.
Tomasetto, C., Mirisola, A., Galdi, S. and Cadinu, M. 2015. “Parents’ Math–Gender Stereotypes, Children’s self-Perception of Ability, and Children’s Appraisal of Parents’ Evaluations in 6-Year-Olds,” *Contemporary Educational Psychology*, *42* : 186–198.
Van Dinther, M., Dochy, F. and Segers, M. 2011. “Factors Affecting Students’ Self-efficacy in Higher Education,” *Educational Research Review*, *6* (2): 95–108.
Weber, K. 2011. “Role Models and Informal STEM-related Activities Positively Impact Female Interest in STEM,”*Technology and Engineering Teacher*, *71* (3): 18.
Weibert, A., Marshall, A., Aal, K., Schubert, K. and Rode, J. 2014. Sewing Interest in E-textiles: Analyzing Making from a Gendered Perspective. In: *Proceedings of the 2014 conference on Designing interactive systems*, pp. 15–24.
Whitton, N. and Langan, M. 2018. “Fun and Games in Higher Education: An Analysis of UK Student Perspectives,” *Teaching in Higher Education*, *24* (8): 1000–1013.
Wigfield, A. and Eccles, J.S. 2000. “Expectancy–Value Theory of Achievement Motivation,”*Contemporary Educational Psychology*, *25* (1): 68–81.
WISE (Women in Science and Engineering). 2021. Analysis of 2021 A-Level Core STEM Entrants Gap between girls and boys awarded A* in Core-Stem subjects widens. WISE Campaign Carlton House Grammar School Street Bradford BD1 4NS: WISE. Available online at: https://www.wisecampaign.org.uk/statistics/classroom/ [accessed 24 June 2022].
Yang, K., Isaia, B., Brown, L.J. and Beeby, S. 2019. “E-textiles for Healthy Ageing,” *Sensors*, *19*(20): 4463.