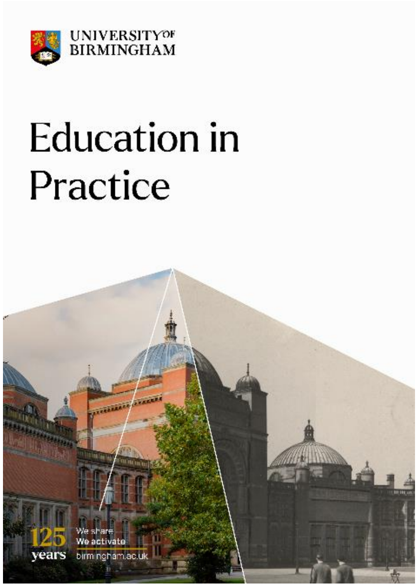

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‘Feeling the code’: Emotions in programming and interventions supporting positivity

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Abstract

Aims. Universities and disciplines may differ, but all face similar challenges in teaching programming, particularly the emotional responses of students learning to code. In our data-driven world, teaching students how to code is vital for their digital literacy and employability. The aims of this project were to understand the emotions students experience in introductory programming modules in different disciplines and contexts, the factors predisposing students towards negative emotional responses and what interventions can effectively promote positivity. **Methods**. We gathered data from MSc Bioinformatics and MSc Data Science students studying both on-campus and via distance learning. Surveys and focus groups explored emotional responses to learning coding languages. We conducted cross-disciplinary workshops with over 30 University of Birmingham staff to identify key barriers and challenging concepts in coding education. **Key findings**. Students report joy more frequently than any other emotion when learning to code. At the same time, students frequently experience frustration related to mismatches between expectations and the reality of coding. Assessment should encompass the learning process alongside the outcomes of coding tasks. While emotional negativity did not differ significantly by programme, fewer negative emotional responses were shown by males or students with prior coding experience. Based on our findings, we developed interventions aimed at humanising the learning experience to foster more positive engagement. **Practical recommendations**. Student expectations need to be managed upfront, normalising the experience of

learning to code and emphasising the need to expect and accept mistakes, as well as taking an iterative approach and adopting a growth mindset.

Keywords: coding teaching, computer science, bioinformatics, programming, emotions in learning, positivity in learning, engagement.

Introduction

Emotions lie at the heart of learning, while the experience of consistent positive emotions is a key requirement for learning in a classroom environment (Meyer and Turner 2006). Learning to write computer code ('coding') is widely recognised as one of the most cognitively challenging and emotionally charged learning experiences (Moskal *et al.,* 2017). Yet, the top three emotions highlighted by studies on coding are frustration, confusion and boredom, which can be classified broadly as negative, while positive emotions such as happiness are comparatively rare (Coto *et al.,* 2022). Considering that coding skills are becoming increasingly important across diverse disciplines, particularly in STEM subjects where big data has become the norm, it is important to understand the emotional experiences of students learning to code and to adopt sensitive approaches to teaching that support students to recognise and express their feelings (Chetty, 2003).

Emotions can be recognised as complex, multifaceted phenomena involving various processes in the body including physiological, affective, cognitive, motivational and expressive processes (Kleinginna and Kleinginna, 1981; Scherer, 2000). They can be measured in many ways from the use of simple self-reports to tracking physiological (e.g., heart rate) and behavioural (e.g., gestures) parameters to enable implementation of intelligent learning environments that track student emotions and respond to them in real-time (e.g., by offering tips for fixing errors in code; Drosos, 2017).

The primary emotion reported in the literature on coding is frustration, which is shown to be a key factor in learner disengagement, dissatisfaction and ultimately drop-out (Coto *et al.,* 2022). However, students also experience a broader range of academic achievement emotions (Pekrun *et al.,* 2002; Kinnunen and Simon, 2011), which strongly correlate with academic performance (Rodrigo, 2013; Lishinksi, 2017). There is a consensus that a certain degree of frustration can improve motivation to work on a problem, but beyond a certain threshold, in intensity and/or duration, the effects can become detrimental (Lee *et al.,* 2011; Coto *et al.,* 2022). This type of effect may occur when students meet 'threshold concepts' (e.g., how to write a 'for' loop) that are often transformative for students in terms of the way they think about a subject (Chetty, 2013).

Almost all investigations of student emotional responses in learning to code have focused on undergraduate computer programming courses, most often in controlled laboratory settings in a US or Philippine context (Coto *et al.,* 2022). Thus, there is a need to compare the emotional responses of students in the UK across different fields of study and modes of learning including on-campus and distance learning (DL). Towards this end, we set out to understand the student emotional experience of learning to code in bioinformatics and computer science disciplines. Specifically: **1)** What are the main emotions students experience in their introductory programming module?; **2)** How do the emotional experiences of novice students compare to students with coding experience?; **3)** How do the emotional experiences of on-campus students compare to DL students?; **4)** Given that sophisticated real-time interventions are out of reach for most teachers in practice, what simple interventions might help to improve the emotional experience of students learning to code?

Methods

We began by informally observing patterns in the learning experiences of students on our MSc Bioinformatics by distance learning programme at the University of Birmingham. Students often experienced what can only be described as a "system shock" in learning to code for the first time, and the feelings that arose in response seemed to present an even greater challenge than the technical aspects of learning to code. The need to investigate the feelings involved and find a way to humanise the experience of learning to code was reinforced by a staff workshop on teaching introductory coding. The workshop drew academic and professional services staff from across the University, spanning many disciplines (e.g., psychology, languages, biosciences, computer science, mathematics, IT services).

A collaboration arose that enabled us to investigate the experiences of students in two subject areas, bioinformatics and computer science, and compare the experiences of students learning in person on-campus in Edgbaston compared with those learning online via distance learning. There is a clear parallel here between teaching introductory coding and teaching introductory statistics and/or research methods, both of which combine highly demanding academic challenge with an emotionally charged experience, including for example the widely reported phenomenon of statistics anxiety (Bromage *et al.,* 2021). The target populations in this study included students from the School of Computer Science enrolled in the MSc Data Science programme, with a cohort size of ~120 per year (and a handful of students from the MSc Fintech or MSc Responsible Data Science); and students in the MSc Bioinformatics programme, with a cohort size of ~40 students per year on-campus and ~25 students per distance learning cohort (with 3 cohorts per year).

Student emotions survey

Students were invited by email and via announcements on the virtual learning environment Canvas to participate in a 15-minute Microsoft Forms survey on the emotions they experienced during an introductory coding module during the MSc Bioinformatics or the MSc Data Science programmes. Students were asked to name their emotions by selecting words from Plutchik's wheel of emotions (Plutchik, 2001) (**Figure 1**; Semeraro, 2021, p. 6-7). When alternative words were used to express emotions, these were standardised using the Plutchik Wheel; each was independently recoded, and a consensus-based conversion dictionary was developed and agreed upon by at least three individuals. Survey responses were anonymised prior to data analysis.

Negativity scoring

An adapted 5-point Likert scale was used (Bieleke *et al*., 2021) to develop an overall adjusted negativity score per survey response, where the most negative response (strongly disagree) to a statement (e.g., 'I am confident when coding') would be three points while neutral or positive responses score zero. For questions requiring named emotions, two negative emotions scored two points while neutral or positive emotions scored zero points. Negativity scores were adjusted based on the number of relevant questions participants answered and were compared between groups using the Wilcoxon Test.

Thematic analysis

Responses were drawn from three free-text survey questions exploring what aspects of the module worked best to help students to manage their emotions, suggestions for improvement, and any other aspects of their emotional experience students wished to share. An inductive thematic analysis approach was used, following Braun and Clarke's (2006) five-phase process: familiarisation, theme generation, review, definition, and final reporting. Two key questions guided the analysis: what were the similarities and differences between on-campus and DL student responses? and how did DL student responses differ between cohorts with and without interventions?

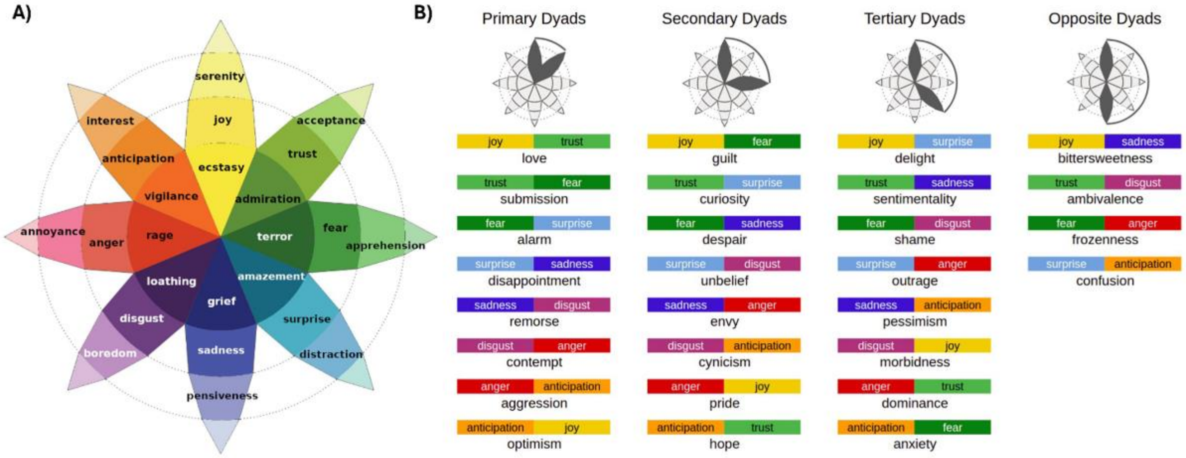

Figure 1: Plutchik's wheel of emotions. A) 8 primary emotions shown as petals on a flower with three degrees of emotional intensity from lightest (lower) to darkest (higher). B) Dyads arising from combinations of petals. Reproduced from Semeraro et al. (2021), pp. 6-7.

Interventions to humanise the experience of learning to code

For cohort 5 of the DL bioinformatics programme, we implemented interventions to improve the student experience of learning to code by building connection between students and staff, normalising the process of learning to code, and shifting the focus from purely technical competency to core transferrable skills. Interventions included a live optional online 'coding clinic' in the otherwise fully asynchronous course, reframing of online discussion board questions around the experience of learning to code rather than focusing purely on technical know-how, and informal weekly videos with reflections from the module lead. Topics for the reflections included: experiences of the emotional rollercoaster, challenges of learning to code when considered as analogous to learning a new language, personal tales of failure, frustration and perfectionism, and the need to take an iterative approach (your code will never work first time). The revised summative assessment included a short answer question requiring reflection on the skills acquired during the experience of learning to code and identification of good practice to take forward into future modules.

Student focus groups

We held two focus groups, the first in Jan 2023 with 4 students from cohorts 1-4 of the bioinformatics DL programme and another in June 2023 with 3 students from cohort 5. Discussions were based on two orienting questions: 1) Building on the information you have already provided in the survey, is there any aspect of the emotional experience of learning to code that you would like to discuss in more detail? and 2) What kinds of learning support or resources would you like to have to help you with learning to code? In the second focus group, we introduced a third question to evaluate the impact of the interventions employed.

Staff workshop

A workshop was attended by more than 30 academic and professional services staff involved in teaching coding across disciplines. Participants worked in small groups to discuss student reactions to coding, their triggers and impacts, the aspects of coding that students struggle with most, and how we can best support as teachers.

Data visualisation

Box plots were generated with the ggplot2 package (Wickham, 2016) and radar charts were generated to represent the 20 most frequently expressed emotions using the fmsb package (Nakazawa, 2024) in R version 4.5.0.

Results

The student survey on emotions in coding received 117 responses with demographics summarised in **Table 1**.

Common emotional responses – from joy to frustration

To explore the range of emotions experienced during coding tasks, students were presented with five common scenarios and asked to name their two strongest emotions for each (**Figure 2**). ‘Joy’ was the only emotion featured in the top three reported emotions across all programmes and cohorts (**Figure 2**). ‘Curiosity’, ‘anticipation’ and ‘anxiety’ also featured among the top 3 emotions (**Figure 2**), indicating that the experience of learning to code is likely akin to a rollercoaster of positive and negative emotions as students oscillate between states where their code is working as expected or not.

Table 1. Survey participant demographics.

		Gender			Age group					
Cohort	**n**	**F**	**M**	**Other/ N/A**	**18-24**	**25-34**	**35-44**	**45-54**	**55-64**	**N/A**
Bioinformatics DL (cohorts 1-4) 2022	27	16	11	0	4	12	7	3	0	1
Bioinformatics DL (cohort 5) 2023	19	10	7	2	3	6	4	4	1	1
Bioinformatics (Edgbaston) 2022	13	4	9	0	7	3	1	2	0	0
Bioinformatics (Edgbaston) 2023	6	4	1	1	3	2	0	0	0	1
Computer Science 2022	25	3	16	6	14	6	0	0	0	5
Computer Science 2023	27	14	9	4	13	11	1	0	0	2

N/A indicates no response given.

Predictably, feelings of annoyance or aggression (*i.e.,* frustration) were reported prominently in all programmes (**Figure 2**). Frustration also featured strongly in the student focus groups and the staff workshop, both of which highlighted how frustration frequently arises at the bridge between concept and application, where students need to progress from understanding the basics of the taught material (e.g., how to write a loop) to applying it to solve real problems. What can be helpful here is to address the mismatch between expectation and reality, by providing opportunities for students to share their experiences of learning to code with staff and fellow students; the staff workshop revealed a strong consensus for the need to assess the process as well as the outcome of learning, allowing students to identify and articulate the skills they have learnt in addition to focusing on the correctness of their code. Both aspects were incorporated into the interventions employed with the DL cohort 5.

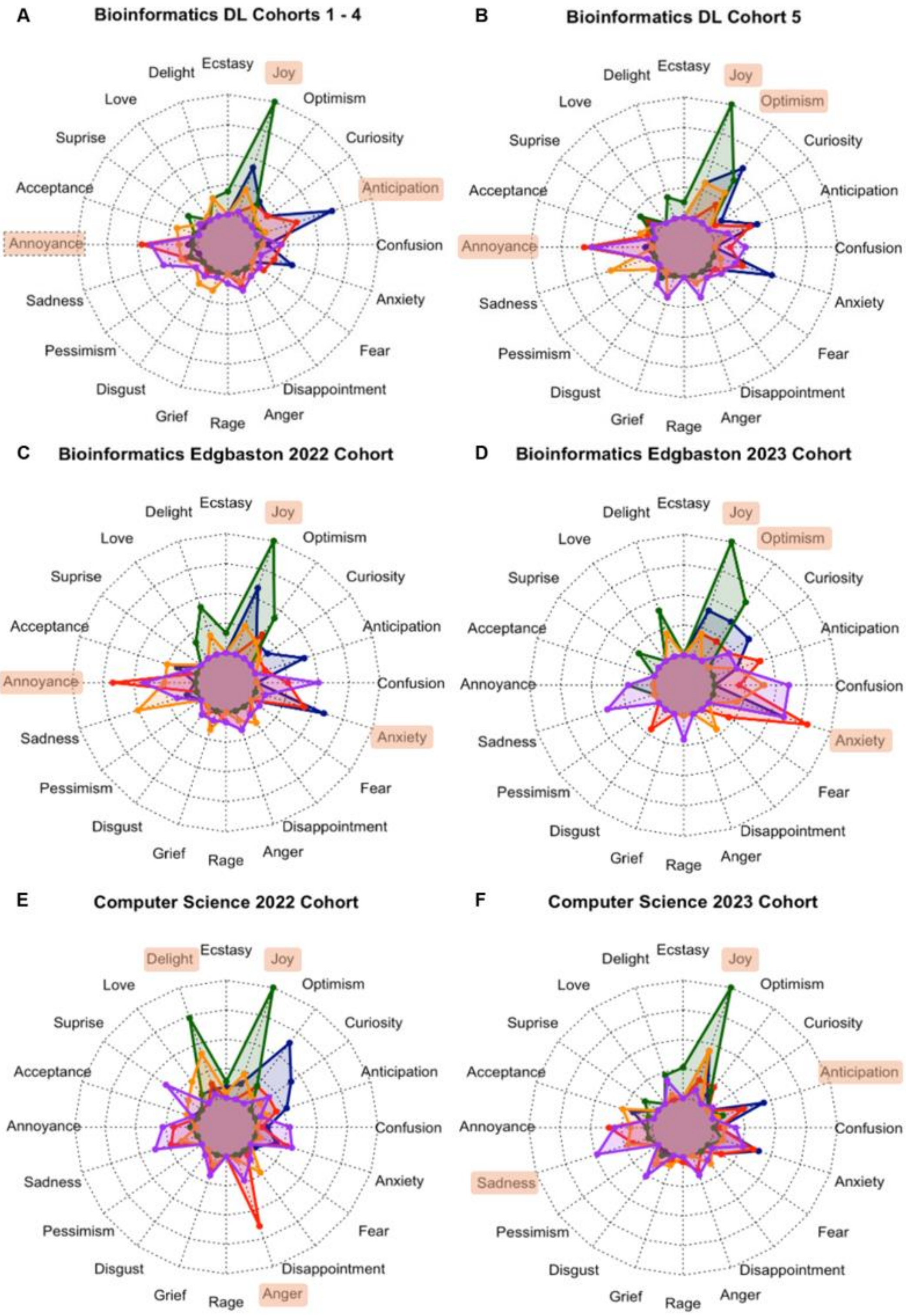

Figure 2: The nature of emotions by programme. Orange blocks highlight the 3 most frequently named emotions per cohort. Coloured lines indicate the response to 5 scenarios presented in the survey, including how students feel when: about to start a coding task (blue), when their code is not working (red), when the code doesn't work but does work after a long time debugging (green), or when using the model answers (orange), and when the code does not work even when using the model answers (purple). Maximum frequency shown by the outer ring represents 26, 16, 12, 5, 22, and 23 responses (A-F).

Factors affecting the degree of negative response to coding

Based on a metric we developed for quantifying negative emotional responses to learning to code, we found that levels of negativity were similar in bioinformatics and data science degree programmes (**Figure 3**). Notably, students in the bioinformatics distance learning cohort 5 where interventions were implemented were less negative than students in previous cohorts 1-4, though the difference was not significant with the small sample size. In the focus group, cohort 5 students reported feeling reassured by hearing about the experiences of other students through discussion boards and live meetings and this helped them to feel that they belong ("I AM a programmer too."). The weekly tutor-led reflections helped students to feel more confident, particularly when they featured relevant issues the students were currently struggling with, such as feelings of being overwhelmed, and provided important reminders of what is important; for example, you do not need to memorise everything or write code from scratch - just knowing what can be achieved with code is enough, then you can use examples to build from.

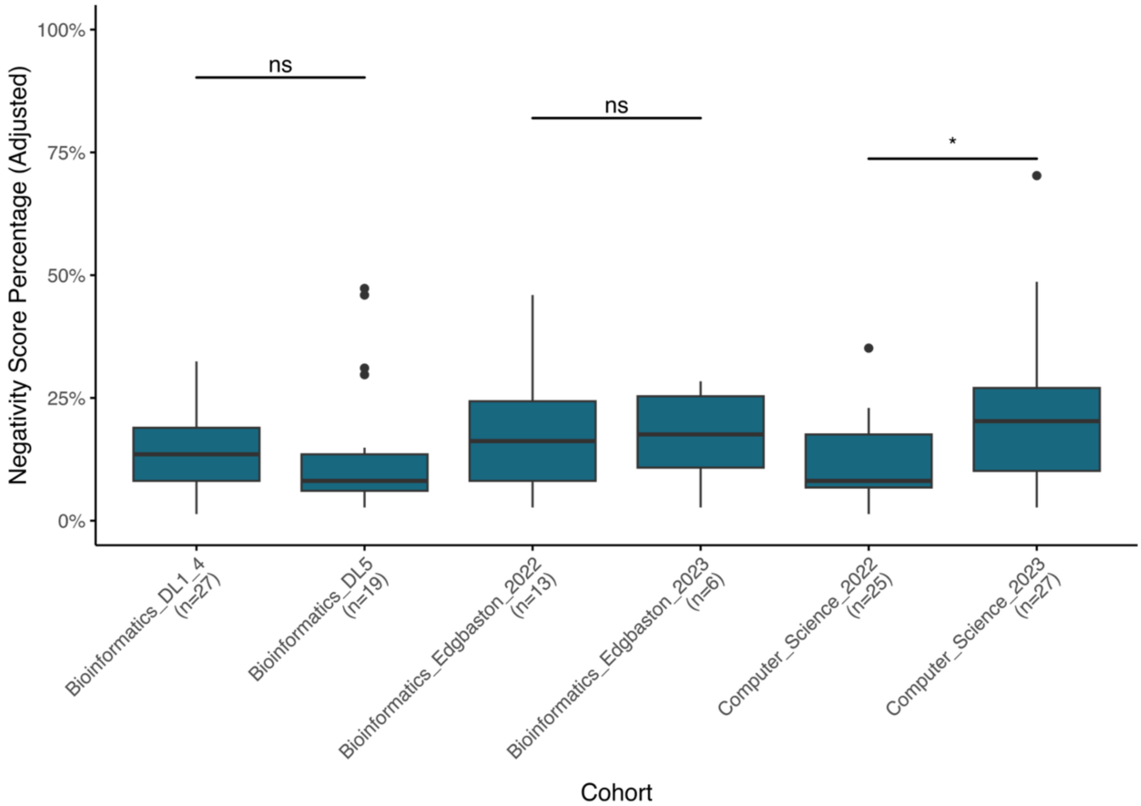

Figure 3: Relationship between negative emotional responses to coding and programme or discipline. Programmes included MSc Bioinformatics on-campus in Edgbaston or via distance learning (DL cohorts 1-4 and cohort 5) and MSc Data Science (Computer Science). Significant p values are indicated with an asterisk ($p < 0.05$) and ns denotes no significant difference.

Across all programmes, the primary indicator of a more negative response towards coding was the level of prior coding experience. Students who had learnt coding previously showed a significantly less negative response (**Figure 4A**) regardless of whether they had learnt coding formally ($p = 2 \times 10^{-4}$) or informally ($p = 9 \times 10^{-4}$). Females expressed significantly more negative emotional responses than males (**Figure 4B**; $p = 0.017$). Therefore, interventions to improve the experience of learning to code need to focus particularly on the experiences of females and the complete novice.

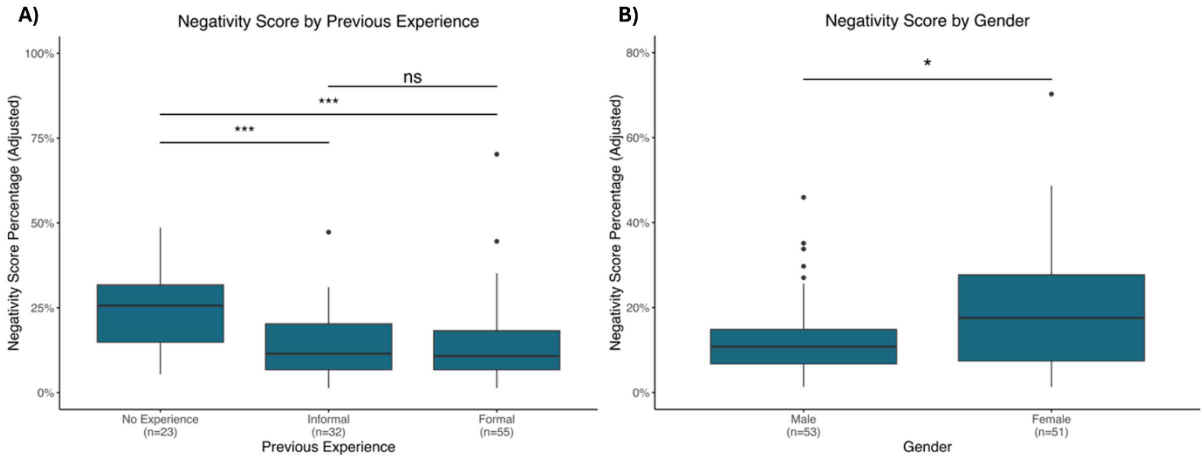

*Figure 4: Relationships between negative emotional responses to coding and level of prior coding experience (A) or gender (B). Coding experience was categorised as none, informal experience or formal experience in a taught course. Significant p values are indicated with an asterisk and ns denotes no significant difference, * denotes p < 0.05, and *** denotes p < 0.001.*

Experiences of students learning on-campus or via distance learning

Student experiences of learning to code were further explored through focus groups and qualitative analysis of free text survey responses. Common challenges reported by both on-campus and DL students included challenges transitioning between coding languages (primarily R and Python), managing inconsistent tutor instructional styles, and becoming independent coders. Emotional responses such as frustration and confusion were common. To help deal with these experiences, human connection and support was highly valued, with peer interaction highlighted by 11.4% of DL and 6.25% of on-campus students, and academic support cited by 13% and 15.6%, respectively. The importance of timely feedback was emphasized by both groups (17.9% DL, 21.9%

on-campus), which students associated with improved motivation and reduced emotional stress.

On-campus students benefitted from real-time group work and immediate feedback during practical sessions, with 12.5% highlighting peer collaboration as a key support. In contrast, DL students reported more intense feelings of isolation, with cohort 1-4 students explicitly noting the lack of live interaction (6.5%) and experiencing greater isolation (17.3%) compared to cohort 5 students (5.6%) who received interventions. DL students also struggled more with time management during self-paced learning, often describing the experience as overwhelming. By contrast, on-campus students had a more structured timetable and fewer reported concerns about course pacing, although 15.6% still desired more time for reflection. Cohort 5 students clearly benefitted from the interventions including live Q&A sessions and weekly reflections, helping them to feel more connected to the programme, with one student stating that it made them feel "*less isolated and more supported*." Compared with 15.4% of cohort 1-4 students reporting feelings of being overwhelmed, only 7% of cohort 5 students felt overwhelmed by their work.

Discussion

We have shown that students in different disciplines frequently report positive emotions such as joy, in contrast to the three most reported emotions in coding: frustration, confusion and boredom (Coto *et al.,* 2022). Progress is never linear, and frustration is absolutely OK, but ultimately there is joy to be found in coding, which we should highlight and celebrate with students. Combining quantitative and qualitative analysis of the survey data with qualitative analysis of focus group outcomes, we conclude that teachers can make simple, practical interventions in introductory coding courses to making learning to code a substantially more positive experience for students, where they feel better supported and less overwhelmed.

We recommend that when teaching introductory coding, student expectations are managed upfront, to temper what can otherwise be a system shock of adapting to a new way of working. The experience of learning to code can be normalised by providing opportunities for community reflection with students and staff. Useful discussion topics include getting comfortable with accepting the feelings that often arise when coding (the emotional rollercoaster), the need to make copious mistakes to eventually get your code to work, the importance of taking an iterative approach and adopting a growth mindset. If feelings of frustration are left unattended, they can easily grow into perceptions of not being capable of coding (or a fixed mindset) or of not being good enough. With careful scaffolding of discussion and sharing of selected personal stories, students can come to realise that their frustration is a sign they are committed to solving a problem, and that these are feelings everyone experiences, including the most experienced coders - who also never ‘get it right first time’. They can also begin to recognise the value in attending to their own emotions during the learning process and showing self-compassion. Although community reflections can take place via online discussion boards in the virtual learning environment, there is no substitute for human connection experienced in a live session, a key consideration for distance learning programmes delivered asynchronously. Along with group discussion and reflection, opportunities for more peer-to-peer interaction, e.g., through group-based learning during hackathons, is likely to facilitate normalisation of the learning process and its challenges.

The importance of the learning process can and should be recognised as part of module assessment. In the bioinformatics programme, we required students to submit a short reflection on the skills acquired during the experience of learning to code and identify good practice to feedforward. More generally and considering the evolving ability of Generative Artificial Intelligence to produce correct code, it is important to capture the thinking and learning process, for example by asking students to annotate their code and explain its rationale, to demonstrate understanding of how and why it works. The central importance of making mistakes in learning to code can also be recognised by paying careful attention to the running order of course material. We recommend introducing the concepts and art of debugging from day one to reassure students that making mistakes is expected and is an important part of developing and testing code, no matter their level of experience.

While the above recommendations can make the experience of learning to code more positive for all students, specific attention should also be paid to complete beginners and female students who report particularly negative reactions to coding. For example, interventions may be designed to provide targeted support to students with no background in coding, possibly by working in groups with a range of experience levels. The emotional experiences of female coders and the relationship with academic self-efficacy is worthy of further investigation, though in the meantime, Guest and Forbes

(2024) provide a set of actionable guidelines for teaching coding more inclusively. It is possible that stereotype threat and/or implicit associations between being male and being competent in coding could play a role as female students are aware of their stereotyped inferiority in mathematics and related disciplines. Fine, 2010 describes how the 'deadly combination of knowing and being' (*i.e.*, women are bad at coding and I am a woman) can be a trigger for negative emotions. On the other hand, it is equally possible there were differences between genders in their emotional literacy and/or openness in expressing emotions via the online survey.

Conclusions

Teachers can help students to feel more positive about coding, better supported and less isolated through simple interventions that make space for students to reflect on their experiences and reduce the gap between expectation and reality. These interventions can take many different forms including opportunities for (ideally live) discussion of the challenges, sharing of emotional experience, group work and revision of assessments to adequately capture the learning process. In future, it will be interesting to explore the experiences of particular groups of students (e.g., females) and the extent to which our findings may be replicated in other disciplines, levels of study and at other UK Universities.

Acknowledgements

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Statement on ethics

The survey, focus groups and data analysis followed the ethical guidelines of the British Educational Research Association, Fifth Edition 2024, and was approved by the ethical review board at the University of Birmingham (application ERN_2022-0499).

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