Exploring engaged research in mathematics and statistics: A-level students on university research placements

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This paper presents preliminary findings from a pilot study on engaged research in A-level mathematics and statistics research placements at a university. Through interviews with students and supervisors, it explores how school students engage with contemporary research, aiming to promote equitable involvement in knowledge production. Findings suggest students engage in research through tasks like solving unsolved problems and translating research, with one student contributing to a research paper. Supervisor expectations, however, may contribute to epistemic injustice by limiting students' contributions and underestimating their potential to co-create knowledge.

Keywords: engaged research; epistemic justice; post-16 mathematics.

Introduction

Public engagement (PE) describes the many and varied ways higher education (HE) activity and research can be shared with the public. HE-PE aims to develop positive relationships between university and local communities and should be "a two-way process, involving interaction and listening, with the goal of generating mutual benefit" (NCCPE, 2020). Most UK academics feel ethically obligated and intrinsically motivated to participate in HE-PE (Wellcome Trust et al., 2015; Watermeyer, 2016) but also need to see the personal and professional value of involvement (Buys & Bursnall, 2007).

Despite academics recognising the need for two-way engagement (Wilkinson & Weitkamp, 2020), in practice, the most common form of HE-PE is often based on a deficit assumption, where academics decide how, what, when, and with whom to share research, and audiences are expected to receive this knowledge without question (Grand et al., 2015). In contrast, "engaged research" (Holliman et al., 2015, p. 3) is a principled approach which suggests rethinking HE-PE with research, transforming interactions between academics and non-academic stakeholders from superficial and sporadic to purposeful and methodical, taking place at different stages of the research process and aiming to create a more equal partnership.

This study explores a two-week student research placement as a potential case study for engaged research, where A-level students are invited to actively participate in contemporary mathematics and statistics (M&S) research within a HE-setting. The motivation for this study comes from the need to explore if and how contemporary mathematics research being conducted in a university school of M&S can be shared with young people in a meaningful way and whether the students can contribute to the production of this new knowledge, moving HE-PE offerings from a top-down outreach approach, towards a more equitable and epistemically just form of engaged research (Holliman et al., 2015).

Theoretical framework

Engaged research

In recent years, there has been growing interest in engaged research with STEM (Grand et al., 2015), which promotes a two-way model of public engagement. Rather than simply disseminating findings, engaged research involves collaboration with non-academic stakeholders throughout the research process, aiming to produce knowledge that is meaningful and beneficial to all parties involved. This approach is underpinned by Irwin's (2021) framework of first-, second-, and third-order thinking. In the context of mathematics, first-order thinking refers to one-way communication of mathematical knowledge, second-order thinking involves two-way dialogue between researchers and publics, and third-order thinking engages multiple stakeholders in reflexive, critical, and policy-relevant discussions about mathematical culture and practice.

Engaged research seeks to address inequities between academic researchers and the wider public by positioning both as contributors to the production of knowledge. However, as Holliman et al. (2015) caution, this model of research can be more time-consuming, labour-intensive, and complex than traditional academic practices. It therefore requires careful planning to ensure that engagement is both meaningful and mutually beneficial.

Importantly, engaged research also holds potential as a route to epistemic justice. As Holliman (2019) argues, involving diverse stakeholders in the research process can help ensure that different forms of knowledge, not just academic expertise, are recognised and valued. In this way, engaged research becomes not only a method of communication but a more equitable and inclusive way of knowing.

Epistemic Justice

Epistemic justice (Fricker, 2017) refers to fairness in knowing and the equitable distribution of knowledge. In the context of HE-PE, epistemic justice challenges the traditional dissemination of research by questioning whose knowledge is valued and whose is excluded. It calls for fair access to knowledge, ensuring that certain groups are not favoured or marginalised in the process. Academics in M&S, whether consciously acknowledged or not, hold power over the knowledge they create when they decide what is shared and who it is shared with. Furthermore, a lack of common understanding of the different publics in HE-PE impacts who gets to have a voice in the research process (Grand et al., 2015). Therefore, the way new knowledge in M&S is developed and communicated has important implications for epistemic justice, specifically how knowledge is distributed fairly and equitably (Medvecky, 2018).

Moreover, epistemic justice also addresses fairness toward the knower, emphasising whose voices are listened to and whose are ignored or undervalued (Medvecky, 2018). For example, a professor of mathematics is likely to be treated as an 'expert' knower over an amateur in any mathematical field, despite only having expertise in one specific area. David Smith, a retired print technician, showed the value of non-expert knowledge in 2022 by making a significant discovery in the field of aperiodic geometry by creating an aperiodic monotile. In traditional models of HE-PE, epistemic injustice is not just a possible risk, but an inherent risk when certain groups, such as school students, are excluded from shaping new knowledge.

Methodology

Philosophical position

This study is grounded in critical social constructionism, which views knowledge as socially and collaboratively constructed through cultural and historical contexts (Berger & Luckmann, 2011). I make no ontological claims about reality (Andrews, 2012) but this study takes the position that knowledge in M&S is shaped by agreed conventions and practices, and builds on prior knowledge, so is therefore socially constructed and open to issues of epistemic injustice. This research takes a critical perspective to examine power dynamics and epistemic justice in the production of knowledge in M&S and to critique, challenge, and transform the deficit model commonly present in HE-PE with research (Horkheimer, 1972).

Evolving research questions

1) How can A-level students collaboratively engage with research in mathematics and statistics, and what are the barriers to engaged research?

2) How can M&S academics foster epistemic justice through collaboratively engaging A-level students in the processes of knowledge production?

Participants

Participants in this research are students and supervisors enrolled in a well-established, national research placement scheme at one UK university. Students are studying one or more STEM A-level, and either come from a low socio-economic background or are the first in their family to attend higher education. Supervisors are academic staff or post graduate students in a university school of M&S.

Data collection

Data was collected in two phases over two years. Phase 1 involved semi-structured, retrospective, recorded online interviews with supervisors from year 1 and 2 of the scheme. Phase 2 consisted of audio-recorded semi-structured in person interviews with students during their placements which took place in year 3 of the scheme. Audio recordings of online interviews were transcribed verbatim and checked for accuracy.

Data analysis

I used reflexive thematic analysis (Braun & Clarke, 2006, 2019), underpinned by social constructionism. The analysis was iterative and interpretive in nature. After the initial familiarisation stage, I used a combination of inductive and deductive analysis, looking for example of engaged research or signs of epistemic injustice across all transcripts (Grand et al. 2015, Fricker, 2017), whilst remaining open to data-driven codes from outside of the expected theoretical framework (Bryman, 2016). This initial coding began after the first interview to allow analysis to run parallel with, and facilitate adjustments to, data collection. For example, an initial deductive code led me to ask subsequent participants about their conceptions of mathematics research.

Memo-writing supported my ongoing reflexivity and served as a means of documenting analytic decisions, developing insights, and theoretical reflections throughout the process (Bryman, 2016; Mohajan & Mohajan, 2022). To organise and conceptualise codes, I used diagramming in the form of mind maps (Buzan, 1995), which allowed for visual exploration of patterns across the data and supported the development of my initial themes. For example, I grouped *helping younger students* and *supporting students from underrepresented backgrounds* into *wanting to help students who are underrepresented in mathematics*, forming a wider developing theme: *Mutual benefit of engagement*.

Throughout this process, I have recognised my own role in making meaning of my codes and themes, and therefore the importance of being reflexive in my approach. In the following section I will introduce and discuss my developing themes: *mutual benefit of engagement*, *understanding mathematical research*, *types of engagement with research* and *perceived limitations for engaged research*.

Results and Discussion

Mutual Benefit of Engagement

The research placements were seen as mutually beneficial, aligning with the NCCPE's (2020) HE-PE framework, which emphasises reciprocal benefits for all involved. Supervisors were motivated to support underrepresented students while gaining research assistance and career development, with one supervisor commenting: "it's a lot of work… but I see this as useful for me", echoing Watermeyer's (2016) observation about the dual purposes of public engagement.

Students, on the other hand, participated for personal reasons such as exploring career options and enhancing their university applications. The prestige of the scheme, coupled with the recognition they received from their schools, was also a strong motivator: "No one else got it, but I got it" and "they were very happy about us getting accepted". Students also reflected on intrinsic motivation, such as being genuinely interested in the research project and the joy of learning new mathematics.

Understanding Mathematics Research

A developing theme found across supervisor transcripts was the need for students to understand the nature of mathematical research. Supervisors emphasised that research is not merely about finding the right answers but involves exploration, trial and error, and learning to cope with the frustration of being stuck. Supervisors also described the importance of teaching students about the research cycle to ensure they understood how their contributions fitted in with the research questions and wider context, even if they couldn't experience the cycle fully within the placement.

For the students, the concept of novelty and originality was also critical. Some students viewed research as addressing unsolved problems: "You don't want to answer a question that's already been answered because then there's no point doing it". Others highlighted the challenge of contributing new insights in a well-established field but described how they were adding to new knowledge in other ways, such as finding counter examples or developing new conditions for existing theorems, as one student described it: "trying to break something that's been done before".

Supervisors and students differed in their perception of M&S research as a specialised type of research. Whilst supervisors discussed mathematics and statistics in very specific terms, students referred more to general research processes, such as

the scientific method or extracting information from literature searches. One student insightfully reflected that "even though mathematicians are really smart, they don't know different fields of maths, because they specialise," challenging the assumption of that mathematical expertise is universal and highlighting the situated nature of knowledge. This reflection may represent a resistance to testimonial injustice (Fricker, 2017), as the student appears to question the idea that only professional mathematicians are legitimate knowers and could be carving out space to value their own developing knowledge.

Types of engagement with Research

I identified three distinct types of engagement with research from the data: *working on mathematical problems*, *conducting research tasks*, and *translating or disseminating research*. Supervisors facilitated students to work on challenging mathematical problems without extensive prior knowledge through creative approaches, such as using accessible games. Students were able to make unique contributions to current research by conducting research tasks including collecting primary data in local communities or gamifying existing research for outreach purposes. Interestingly, the activity of translating and disseminating research, though less traditionally associated with doing mathematics research, was the one that most fostered student independence as they had creative control over the game they created and how they incorporated their supervisor's research into the game play. This shows that design-based or creative methodologies could potentially expand definitions of valid knowledge production beyond the traditional hypothesis testing approach.

Perceived Limitations for Engaged Research

Several limitations were noted by supervisors about the placements, particularly the short timeframe and students' lack of prior knowledge. Supervisors also expressed concerns that certain tasks were beyond the capabilities of A-level students. For example, whilst supervisors emphasised that asking good, novel questions is "one of the main skills in mathematics," they also assumed that students lacked the necessary experience to do so, and so did not create space or guidance for that part of the process. This may constitute an example of hermeneutical epistemic injustice (Fricker, 2017), as students were not given the opportunity or tools to explore how to formulate their own meaningful questions, disregarding them as 'knowers' and limiting their capacity to act as full epistemic agents in the co-creation of knowledge. This arguably positioned them as assistants rather than collaborators in the research.

Furthermore, supervisors did not expect students to produce novel results, and were surprised to find that some contributed more than was expected: "I didn't expect them to go further and produce something really new". One student exceeded prior expectations by making a significant contribution to an unsolved mathematical problem, leading to their name being included on an academic paper and demonstrating that even students with limited prior experience can make significant contributions when given the appropriate opportunities. Interestingly, this highlights both the potential of engaged research to develop a second (or third) order mode of knowledge production (Irwin, 2021), but also of the need to ensure that all students are afforded the chance to ask questions and contribute meaningfully to research processes, to avoid creating or perpetuating issues of hermeneutical epistemic injustice.

Tentative conclusions

Preliminary findings suggest that A-level students can engage meaningfully with contemporary M&S research, with opportunities to contribute in areas like problem-solving and research dissemination. However, misalignments between supervisor expectations and students' capabilities may perpetuate epistemic injustice by limiting students' roles in knowledge co-production. This study highlights the importance of recognising students as active contributors, not just passive recipients of knowledge, and suggests that more support is needed to foster genuine collaboration. Future research will focus on further exploring how engaged research can promote epistemic justice and overcome barriers to student engagement.

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