

Undergraduate research, learning gain and equity: the impact of final year research projects

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ABSTRACT

This study evaluates the impact of undergraduate research on student achievement. It analyses graduating students from 2012 to 2016 at a UK university that requires a research project comprising 25% of final-year credits in most subjects, providing a sample of over 5000 students across the natural sciences, social sciences and humanities. It compares project grades to other final-year grades to gauge the ‘research gain’ or impact on students’ achievement. Multiple regression analysis then determines what factors affect this impact. It finds that students achieve better grades on research projects than the average of other modules. This improvement is larger for students with lower prior achievement, women, and students in the natural sciences, though smaller for Asians and students declaring a disability. The implications are that undergraduate research provides a measurable benefit to all students, but this impact is larger for some, though not all, historically underrepresented or underachieving groups of students.

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Introduction

Undergraduate research is seen as a ‘high impact’ educational practice, meaning that it has been widely tested and research suggests that it increases rates of student retention and engagement, leading to the achievement of benefits in educational learning outcomes, skills and attitudes (Kuh, 2008; Laursen, Hunter, Seymour, Thiry, & Melton, 2010; Lopatto, 2009). These learning gains, which are defined as the improvement in students’ knowledge, skills and personal development over time (McGrath, Guerin, Harte, Frearson, & Manville, 2015), include intellectual skills such as problem-solving and analysis, improved personal initiative and communication, higher tolerance for ambiguity and obstacles in problem solving, ethical conduct, experience integrating theory and practice and improved writing skills (Bauer & Bennett, 2008; Laursen et al., 2010; Lopatto, 2004, 2007, 2010). Research experiences also increase students’ critical-thinking and communication skills (Bauer & Bennett, 2008; Hunter, Laursen, & Seymour, 2007; Seymour, Hunter, Laursen, & DeAntoni, 2004), and these skills are more likely to be developed from undergraduate research than

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other activities (Thiry & Laursen, 2011). Not only do scholars largely agree that this pedagogical approach achieves good outcomes, but there is also evidence that it particularly benefits students that are most at risk of underachieving (Eagan et al., 2013).

Much of the literature has focused upon the natural sciences with less attention paid to the social sciences and humanities (Ishiyama, 2002; Rand, 2016). Further, much of this research is based in the United States, where undergraduate research is often provided as a non-credit-bearing summer or extracurricular experience, typically consisting of a period of time spent in labs, and is limited to select groups of students due to resource constraints (Linn, Palmer, Baranger, Gerard, & Stone, 2015). One study of similar summer research experiences in the UK reports similar improvements in student capabilities and confidence, though no effect on intentions to pursue postgraduate study (John & Creighton, 2011). However, UK higher education tends to view undergraduate research as more universal aspect of undergraduate education in the form of the final year project or dissertation (Parker, 2010), and it is unclear whether the practice would have a similar impact if all students participate. Other 'high impact' practices in the UK, such as internships and work placements, have attracted much recent research and analysis of its contribution to student learning and academic performance in the UK (Mansfield, 2011; Crawford & Wang, 2016; Jones, Green, & Higson, 2017), but undergraduate research has received comparatively little attention, particularly given the prominent place it occupies in higher education in the UK (Healey & Jenkins, 2009).

UK universities award honours degrees to almost all of their undergraduate students and normally require a final year dissertation or research project as a culminating experience (Parker, 2010). Research suggests that the longer and more intensive the supervision of research, the more impact it has on students (Fechheimer, Webber, & Kleiber, 2011; Russell, Hancock, & McCullough, 2007; Taraban & Logue, 2012; Thiry & Laursen, 2011). The final project or dissertation in the United Kingdom operates under similar assumptions, and usually spans the entire final year and comprises a large percentage of the students' final year credits (Parker, 2010). The high levels of participation in final-year undergraduate research in the United Kingdom makes it well suited to test the claims made for it in the United States, where fewer students undertake such activities for shorter periods of time, which creates more of a problem with self-selection and makes it more difficult to tell if better students choose to do research or whether the experience makes them into better students (Eagan et al., 2013).

This study focuses upon a case study which examines student achievement at a mid-sized English university. The university enrolled just over 7200 full-time-equivalent (FTE) students in 2015 compared to a national average of 9200 (Higher Education Statistics Agency, 2017). These students are distributed by disciplines as 40% natural sciences, 40% social sciences and 20% humanities. Almost all students across the humanities, social sciences, and natural sciences are required to complete a yearlong project that counts for a quarter of their final year. This widespread practice of undergraduate research across programmes provides an opportunity to analyse differences across disciplines and look at its direct impact on students, particularly those from groups who have traditionally been underrepresented or underachieve in higher education.

The study examines students' grades for their final research projects to see if their performance improves or declines, relative to their other grades. This difference is analysed to evaluate the impact of other factors, including discipline of study, gender, ethnicity, family background, and previous academic performance. Results are analysed across five

successive graduating cohorts of home students from 2012 to 2016, which provides a sample of 5027 students in total. The value of this analysis comes from this large sample that allows comparison across disciplines outside the natural sciences and which can analyse actual grades, rather than self-reported outcomes, to more precisely indicate the relative impacts of different factors on student achievement.

Literature review

Though scholars do not agree on a single definition, the Council on Undergraduate Research (CUR) define undergraduate research as ‘an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline’ (CUR 2017). Others argue for a more inclusive, wider definition. Brew (2010) expands upon the CUR definition to include research-based activities and would allow for contributions to the discipline and/or understanding. This broader approach echoes Boyer (1996), who also argued for an expansive definition, claiming that research can take the forms of discovery, integration, application, and teaching and that these should also apply to the efforts of undergraduates. This analysis uses the CUR definition to focus more narrowly upon the more formally organised and recognised independent research projects carried out by undergraduates in the UK.

Impacts of undergraduate research

Many studies may include a wide variety of inquiry-based activities as research, such as routine lab work or participation in experiments as a subject or observer rather than as a co-researcher. Much of the literature on undergraduate research evaluates summer or other extracurricular experiences outside of credit-bearing, term-time teaching. Most research also uses self-reported data from student surveys in order to evaluate the impact of these experiences (Lopatto, 2004; Seymour et al., 2004). The diversity of experiences that are classified as undergraduate research makes it very important to identify exactly what practices and benefits are being analysed. While the literature is overwhelmingly agreed that there are benefits to undergraduate research, there is an absence of widely generalisable evidence from most studies, where fewer than one in ten validate student self-reports with other data to measure learning gains (Laursen et al., 2010; Linn et al., 2015). There is also the question of why most of this research focuses upon the natural sciences. Approaches to undergraduate research in the natural sciences, which already include labwork in the curriculum and can include undergraduates on larger research teams, are not as adaptable to the social sciences or humanities. Undergraduate research in these latter disciplines often takes the form of independent projects or honours theses and dissertations, which are graded for credit and, subsequently, tend to emphasise the efforts of the individual student and often forbid collusion with other students (Lopatto, 2006; Rand, 2016). Few studies compare or evaluate across the natural and social sciences (Hathaway, Nagda, & Gregerman, 2002; Russell et al., 2007), and studies comparing the natural sciences, social sciences and humanities in the same analysis are even rarer (Hu, Kuh, & Li 2008; Lopatto, 2006; Parker, 2012), so little is known about the impact of these differences across disciplines.

There is much research analysing student surveys of undergraduate researchers from summer programmes. The results demonstrate self-reported benefits that indicate learning

gains across several broad categories. These areas include personal gains such as confidence, intellectual gains such as critical thinking, communications skills, and career benefits by increasing skills and aspirations for postgraduate degrees (Hunter, Weston, Laursen, & Thiry, 2009; Lopatto, 2004, 2007, 2010; Seymour et al., 2004). The development of career aspirations for scientists is found to be a benefit across many studies. Developing such aspirations is a goal for a range of national and more local policies and programmes in the United States to alleviate the shortage of graduates in science, technology, engineering and mathematics (STEM) subjects (Hunter et al., 2007; Russell et al., 2007). Much of the importance of undergraduate research is justified in these pragmatic terms, and the implications are particularly important for traditionally underrepresented groups in higher education.

Equity impacts of undergraduate research

One of the most important claims consistently made in the literature is that undergraduate research experiences benefit underrepresented student groups and those from historically underachieving groups even more than the average student. Undergraduate research experiences are found to directly improve the retention of ethnic minority students (Gregerman, Lerner, von Hippel, Jonides, & Nagda, 1998; Pascarella & Terenzini, 2005). In addition, it can also increase retention of students with lower achievement (Gregerman et al., 1998) and low income students (Ishiyama, 2001), though Hu et al. (2008) found that low achieving students did not benefit from inquiry-based activities, while middle and high achieving students did benefit. Similarly, Taraban and Logue (2012) found that students with higher grades benefited more from research experiences. In addition to retention, undergraduate research has been found to increase the skill preparation and intentions of ethnic minority students to seek postgraduate degrees in STEM subjects (Bauer & Bennett, 2008; Hathaway et al., 2002; Hu et al., 2008; Ishiyama, 2002; Lopatto, 2004; Russell et al., 2007). Eagan et al. (2013) provide an overview of this literature as well as a full discussion of its limitations, while their own analysis largely confirms the findings from this body of research.

Methods

This study evaluates the impact of final-year undergraduate independent research projects (ISPs) on students' achievement and what factors affect this impact. The ISPs are organised as yearlong modules that usually account for 25% of final year credits and usually take the form of 8,000 to 12,000 word dissertations or equivalent projects. The sample includes grades for five annual cohorts of final-year students between 2012 and 2016. In order to evaluate how students engage with this research project and how that is linked to academic achievement, students' grades on their ISP are compared to the average for their other final-year modules. The difference between the ISP module and that average, referred to here as 'research gain', is an indicator of the direct, tangible gains from this research experience.

Using direct measures of student achievement through grades has many advantages but also some limitations. It assumes that the process for student marking is relatively similar across different markers and disciplinary subjects. The UK higher education sector boasts a rigorous system of quality assurance, using national curricular outcomes for degrees, subject curricular benchmarks, periodic institutional audits, double marking of some student work, and external examiners for each degree programme. While these systems work to reduce

those biases, few would claim they entirely remove them. The use of a single institutional case study acts to minimise the variations in organisational culture experienced by these students, but that strength also increases the risk of measuring effects that are particular to the institution. Further, the design will put controls in place to account for differences across disciplines and time. The large sample across most of the university cohort helps to mitigate any impact from differences across individual markers. While not unaware of the difficulty in performing such large-scale studies, the benefits of being able to measure actual, vs. reported, grades allows a precision in the analysis that is hard to achieve without such detailed measures. The grades students receive function well as a proxy for learning gains, though they may not be precise measures of specific learning outcomes.

The benefits from research experiences are often claimed to be much broader and longer term than this specific measure. Its role in boosting aspirations for postgraduate work is an example. However, this study's narrower approach is valuable because it gives a defined and valid indication of the impact of the key component of the undergraduate honours degree and also shows the impact of institutional and student background variables. The claims for the importance of undergraduate research and its particular role in boosting student engagement would suggest that, on average, the grades for the research project should be higher than for other classes, though this assumption is not certain. The literature on research methods teaching in the social sciences suggests that demanding classwork may help students achieve good learning gains through challenging expectations but may also result in lower grades and more negative student evaluations (Rand, 2016). However, the literature on undergraduate research has not identified any tend towards negative student perceptions or problems with persistent underachievement. More the opposite, it is seen by students and staff as a positive and productive part of their education (Lopatto, 2004, 2009). Therefore, there should be a positive gain between the ISP and the average of other final-year grades.

Individual factors and academic achievement

The gain in grade between the ISP and the average of other classes, referred to in this study as 'Research Gain', is used as the dependent variable in a multiple regression to analyse the impact of student characteristics and discipline of study. Analyses of UK higher education outcomes consistently demonstrate that students from low socio-economic groups achieve lower attainment and progression outcomes, even when controlling for other factors (Broecke & Nicholls, 2007; Mountford-Zimdars et al., 2015). The literature on the benefits of undergraduate research in the United States frequently finds that its impact is the same or larger for traditionally disadvantaged students than it is for other students. It is also seen as a key factor to attract women into pursuing higher degrees in STEM subjects. Evidence for the direct benefits of research for women is more mixed, with two studies (Kardash, 2000; Taraban & Logue, 2012) finding lower benefits than for women and three studies (Lopatto, 2004, 2007; Russell et al., 2007) finding a higher impact. However, wider benefits such as retention and intention to pursue postgraduate degrees have been found to benefit women, ethnic and racial minorities, and students from less advantaged family backgrounds (Eagan et al., 2013). Students identified as disabled in the UK also demonstrate slightly lower overall levels of achievement than other students (Mountford-Zimdars et al., 2015), though there is no evidence that this effect would have any impact on the benefits from research.

Based on this prior research, the following characteristics were included as independent variables in the analysis:

- **Prior Attainment:** this was measured by using students' average grade mark from the previous year.
- **Gender:** this was measured using students' self-reported gender, coded as 'male', 'female', or 'other'. A binary variable was coded '1' if the gender was 'female'.
- **Ethnicity:** this indicates students' self-reported ethnicity and measures the two main minority ethnic groups in the UK. Two binary variables were entered with one containing a coding of '1' for people self-identifying as Black and another with '1' for Asian.
- **Disability:** This is measured by using a binary variable with a coding of '1' where students are registered with the Higher Education Statistics Agency (HESA) as having a disability.
- **Low participation neighbourhood (LPN):** this binary variable indicates whether the student comes from an area with low-rates of participation in higher education. This measure is used as a proxy for social class and is derived from HESA's Participation of Local Areas (POLAR3) database, which is used as a proxy for socio-economic background. It identifies participation rates in higher education by postcode. Students from postcodes in the bottom the two quintiles for participation are coded as '1'.
- **Discipline:** this variable indicates whether a student is enrolled in a humanities, social sciences, or natural sciences discipline as the primary subject. It is measured by creating two binary variables, one of which is coded '1' for natural sciences, and one of which is coded '1' for social sciences, leaving the humanities as the default category. In the UK, psychology is counted as a biological science unless a degree curriculum contains little scientific content. The main accreditation body, the British Psychological Society (BPS), emphatically refers to the subject as a scientific discipline and incorporates that assumption into its professional standards. Most psychology degrees in the UK are accredited by the BPS, so psychology is included as a natural science.
- **Year:** this variable controls for the year of graduation, covering five years from 2012 to 2016. There are four binary variables, each of which is coded '1' for each of the years from 2013 to 2016. These variables account for each year to control for changes in student outcomes across the sector as a whole by year and for differences in cohorts not accounted for by the other variables.

Undergraduate research has been claimed to provide greater academic benefits to the more advanced students. Taraban and Logue (2012) and Hu et al. (2008) found that the impact of undergraduate research depended on student ability. Universities in the United States often reserve honours programmes, where students must produce a major research project, for select groups of more able students, which reinforces the perception that research is an elite pursuit. However, most subjects in the United Kingdom require undergraduate research of all their students, so it is unclear if this same effect would hold or possibly be accentuated by having a larger and more diverse cohort of students pursuing research (Parker, 2012).

Greater benefits for higher achieving students have not been found in research on other, wider benefits. For example, retention was found to improve more for less academically able students (Gregerman et al., 1998) and students from low-income households (Ishiyama,

2002). Research projects are seen as excellent preparation for postgraduate degrees, and the literature suggests that this experience improves student intentions to pursue further degrees, particularly for women, minorities and students from low-income households. This analysis will test the sometimes contradictory evidence on who benefits from undergraduate research by including prior attainment and identity variables. Finally, much of the literature on undergraduate research is based upon the natural sciences. Scientific research with large-scale projects including research groups of academic staff, postgraduate supervisors, and undergraduate members can be effective but is largely inappropriate or unrelated to practice in the humanities and social sciences (Lopatto, 2006; Rand, 2016). The question then remains of whether the natural sciences benefit more from undergraduate research because of the disciplinary nature of knowledge acquisition and more appropriate models for undergraduate participation. The literature is ambiguous, with Taraban and Logue (2012) finding that benefits differed by discipline while Bauer and Bennett (2008) found they did not.

Previous research points towards a number of findings about undergraduate research that inform the following predictions:

- (1) *'Research Gain' will be positive*: if undergraduate research experiences are so unambiguously positive, then student attainment in the ISP module should outperform average student attainment in other modules.
- (2) *Natural Science Students will have a larger Research Gain than other students*: the research literature suggests that the models of research, teaching and disciplinary learning in the natural sciences may be more suited to pursuing undergraduate research.
- (3) *Prior Attainment will have a positive impact on Research Gain*: This prediction tests the claim that less able students will improve more from research experience than students with better academic attainment. The literature is not consistent on this matter, and it has not analysed whole cohorts of students in which everyone is expected to complete research projects.
- (4) *Low Participation Area will have a positive impact on Research Gain*: Ishiyama (2001) found that research experiences improved retention and postgraduate school acceptance rates for first-generation university students. This prediction tests whether students from historically underrepresented areas gain more from undergraduate research than others.
- (5) *Gender will have no impact on Research Gain*: this prediction follows the findings in a majority of studies that women and men benefit equally from research experiences.
- (6) *Black Ethnicity will have a positive impact on Research Gain*: this prediction tests the finding that ethnic minorities benefit more from research experience than others by testing the effect for each group.
- (7) *Asian Ethnicity will have a positive impact on Research Gain*: this prediction tests the finding that ethnic minorities benefit more from research experience than others by testing the effect for each group.

Results

Graduating students attained a mean mark of 61.96 in their ISP module while they attained an average of 60.73 across all other modules in their final year. The difference between the two was 1.23 with a standard deviation of 6.49, meaning students outperform their average class grade by 1.21 points on a 100 point grading scale. A comparison of means *t*-test confirmed that this difference is statistically significant at $p < .001$. This spread of marks roughly follows a normal distribution, though the grades are somewhat heavily clustered around the average mark. Given that a grade of 60 is the boundary between an upper first (2:1) and lower first (2:2) degree classification, that heavy clustering of marks is not surprising. Table 1 presents descriptive statistics from the overall sample. The proportions of particular groups in the sample appear reasonable for a population of university students who are resident in the UK with no particular outliers. Students performed better in their dissertation relative to other classes across all three disciplinary areas.

The results for the multiple regression analysing the determinants of Research Gain produced overall model results that are significant at $p < .001$ with an adjusted R^2 of 0.19. These figures suggest that the model explains only a small proportion of the variation in Research Gain. However, the dependent variable measures the improvement in grades between the research project and an average of other classes. It is unlikely that any model would explain a large proportion of this variation, and the overall fit of the model is not of as much interest as the relative impacts of the independent variables. Table 2 summarises the results of the multiple regression analysis of the effects of both student characteristics and discipline on the improvement in grades earned for undergraduate research projects compared to other final year classes.

Table 1. Descriptive statistics and sample frequencies.

	Mean	Standard deviation
Research Gain (Overall)	1.2	6.5
Sciences	1.8	6.4
Social Sciences	0.5	7.8
Humanities	0.8	4.2
Prior Attainment	59.9	6.5
Disability	13.7%	
Low Participation		
Neighbourhood	26.3%	
Gender		
Female	50.7%	
Male	49.2%	
Other	0.1%	
Ethnicity		
White	82.9%	
Black	5.4%	
Asian	11.1%	
Other	0.6%	
Discipline		
Sciences	43.2%	
Social Sciences	32.0%	
Humanities	24.8%	

Table 2. The effects of student characteristics and discipline on benefits from undergraduate research.

Variables	Unstandardised coefficients		
	B	Standard Error	Significance
(Constant)	5.981	.834	.000 **
Sciences	.894	.231	.000 **
Social Science	-.554	.247	.025 *
Prior Attainment	-.085	.013	.000 **
Disability	-.528	.266	.047 *
Low Participation Area	.218	.207	.293
Female	.722	.186	.000 **
Black	-.286	.410	.485
Asian	-1.359	.298	.000 **
Y2013	-.281	.283	.322
Y2014	-.151	.279	.589
Y2015	-.234	.291	.421
Y2016	.198	.289	.494

* $p < .01$;** $p < .001$.

Discussion

The descriptive statistics already indicated that the Research Gain is positive, which meets the expectations of the study, but how important is that figure? Evaluating the impact of a gain in 1.2 in the average grade is difficult, but this improvement could be very important in the British context, where degrees are given on overall classification of First Class, Upper Second Class (2:1), Lower Second Class (2:2), and Third Class, which roughly approximate to A, B, C and D. However, the entire degree is given a single classification for each student rather than a more specific numerical score such as a grade point average. Generally, a First is indicated by a mark of 70+, an Upper Second (2:1) by 60+, Lower Second (2:2) by 50+ and a Third by 40+. The overall classification reflects the grades received on the preponderance of modules with the final year weighted more heavily. The student average in the final year without the research project is just on the line (60) between a 2:1 and a 2:2. That difference matters a great deal to students, since over two thirds of degrees now attain a classification of 2:1 or First. Dropping below that line could be much more detrimental to a student's future prospects than a simple reduction in 1 point would suggest. The ISP module makes up 25% of the final year grades, which are more heavily weighted in deciding the final degree classification than grades from previous years, so the relative importance of this grade is very high.

The regression results show that six of the eight predictor variables return statistically significant coefficients. These coefficients indicate the impact of each variable on the difference between the ISP module and the average of other final year modules on a 100 point grading scale, which makes it easier to interpret the size of impact for each variable, bearing in mind that the average improvement across all students was 1.2. The discipline variables were both significant but in opposite directions. The natural science variable was of most interest, returning a coefficient of .894, meaning that natural science students' research projects outperform their yearly average by almost a full point more than students in the Humanities. Further, the significant, negative coefficient of $-.554$ for Social Sciences was not predicted and means that, while these students still get a higher average score on their research project

compared to other classes, this improvement is half a point lower than humanities students and 1.4 points lower than natural science students, on average. This result is consistent with arguments that the experimental sciences may be better adapted for students to carry out undergraduate research (Hunter et al., 2007; Lopatto, 2006), though it should again be noted that all three disciplines benefited overall. The reason for social sciences performing worse than other disciplines, and the humanities in particular, is unclear and has not been a key finding in previous research. It could be an institutional effect or just a reflection of the particular organisational cultures of those subjects. Taraban and Logue (2012) found that the benefits of research experiences did vary across different subjects. There have been too few studies that compare across subjects and institutions to provide any clear answers to why there were such differences across all disciplines.

The findings for Prior Attainment, which was measured through the average of all modules in the previous year, returned a significant coefficient of $-.085$. That means that a student with a final year average of 50 would achieve a grade on their research project that outperforms their yearly average by .85 points more than a student with an average of 60. This difference is not trivial, since the average gain for the research modules for all students is 1.2. It suggests that, while all students benefit on average from taking part in undergraduate research, students with lower academic grades benefit more from this experience than those with higher grades. This result is important because previous research (Kardash, 2000; Taraban & Logue, 2012) using self-reported data from students found the opposite effect. While other studies have found that lower achieving students benefited in other ways, such as retention and intention to pursue further studies, this study uses actual grades to demonstrate that lower achieving students benefit more from undergraduate research than higher achieving students.

There was no prediction for Disability, but it has been associated with an achievement gap in higher education in the UK. (Mountford-Zimdars et al., 2015), so it was included as a control variable. It showed a significant negative impact on the higher grades associated with undergraduate research compared to other classes, with an average decrease of .528 point for students with disabilities. It would appear that the conditions that students in this classification encounter can create greater obstacles to carrying out research projects than for other types of coursework, but the data were not detailed enough to allow analysis of the impact for particular types of disability. This result is of some concern and indicates the need for more research to ascertain if particular conditions have more severe impacts and what sorts of institutional interventions lessen this effect.

The coefficient for Low Participation Area was positive but insignificant, so it fails to support the prediction students from low participation households benefit more from undergraduate research than other students. The finding of no significant effect suggests that student from different family backgrounds all benefit from undergraduate research experiences in the same way as other students.

The coefficient for female students was positive and significant. The size of the coefficient indicates that women improve on their research project grades, relative to other grades, at .722 points more than men. Prior research had found mixed effects from gender, with women achieving more in some studies with men achieving more in others. This result clearly shows that women benefited from research more than men using direct measures of student achievement, so there may be a different result when using self-reported gains. There was no obvious interaction with subject choice that might have influenced this effect.

While there are often gender imbalances across higher education disciplines, they did not appear much in this sample, where women represented 56% of natural science, 49% of social science and 52% of humanities students. Further, most prior research took place in the United States, so cultural differences may play a role. Since prior attainment is already controlled for in the analysis, the data do not provide a clear answer to why women benefit from research more than men.

The results for Black students are insignificant, indicating that they benefit from undergraduate research experiences the same as other students. Research in the United States clearly suggests that ethnic minorities may gain greater benefit from undergraduate research than other students, but this study did not find such an effect. The reasons could be cultural, related to the particular institution in this study, or the use of a direct measure of achievement may produce different results from self-reported data.

The results for Asian students, however, showed a large, negative, statistically significant impact, which was the opposite of the result expected and contradicting previous research findings. The size of the coefficient indicates that Asian students improve on their research project grades relative to their other grades 1.359 points less than for Whites, which is larger than the overall average benefit from the research experience. There is no obvious correlation with disciplinary field, where Asian students represented 14% of students in the natural sciences and humanities and 9% in the social sciences. These are home students, so it is not a case of international students encountering cultural or language barriers. It is also not due to academic ability, as that measure was already controlled through prior attainment. There are no obvious answers to why this effect is occurring, but it is a disturbing trend that deserves more detailed attention to see if the effect is more widespread. There are obvious cultural effects operating here, where Asians are the largest ethnic minority group in the UK and do experience an educational achievement gap. However, the results are not easily interpretable when Black students did not suffer from such a gap in this study.

Conclusion

This analysis confirms previous research findings that undergraduate research benefits students even more than more traditional classroom experiences. In particular, it benefits students in ways that promote more equitable outcomes in higher education by providing greater benefits to students with lower academic achievement than for those with higher grades. It also provides more benefits for women than men, and it benefits students in the natural sciences more than other disciplines. The finding of negative impacts for Asian and disabled students was unexpected and troubling, but it is unclear if that effect is institutional or more widespread. It could also be particular to the UK, where Asians constitute the largest minority group in the country. There are some obvious limitations to this study. It analyses students from a single institution, which raises the usual problems of generalising the results. While only a single institution, the university is not atypical and the sample includes a large number of home students over five years, which brings a greater depth of detail and allows more reliable measurement of the relationships between the benefits of undergraduate research and student characteristics.

The clear advantage of this analysis come from measuring actual, rather than reported, grades across a large sample of students. Grades provide one clear measure of learning gain that enables analysis of the impact of other student and institutional characteristics.

This study provides clear support for many of the findings in the literature. In particular, undergraduate research benefits all students, and it can provide even larger benefits for some, though not all, traditionally disadvantaged groups. This approach to teaching is clearly beneficial to students and should be promoted and developed by institutions and staff in higher education as a key approach to further improve undergraduate education.

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