Chapter 8
Investigative School Research Projects in Biology: Effects on Students

Wilton G. Lodge, Michael J. Reiss, and Richard Sheldrake

8.1 Context

School biology often entails undertaking practical work, which is generally intended to help students gain conceptual understanding, practical and wider skills, and understanding of how biologist work (Kampourakis & Reiss, 2018). However, the literature on practical work in school science indicates that it often achieves less than its proponents intend (Abrahams & Millar, 2008; Gatsby Charitable Foundation, 2017). Investigative school research projects are relatively uncommon, relative to other types of practical work, such as confirmatory practical activities (intended to produce the same result for all students every time), but it has been argued that they can give students a better understanding of what it is like to undertake authentic science. A systematic review found that investigative student science research projects could have a number of benefits for students including the learning of science ideas, affective responses to science, intentions to pursue careers involving science, and development of a range of skills, some specific to practical work and others, such as collaborative teamwork, more general (Bennett et al., 2018). Nevertheless, this same review concluded that further work is needed to enhance the quality of the available evidence and to explore more fully the potential longer-term benefits of participation in such projects at secondary school level.

W. G. Lodge (✉) · M. J. Reiss · R. Sheldrake
UCL's Faculty of Education and Society, London, UK
e-mail: wilton.lodge@ucl.ac.uk; m.reiss@ucl.ac.uk; r.sheldrake@ucl.ac.uk

K. Korfiatis et al. (eds.), *Shaping the Future of Biological Education Research*, Contributions from Biology Education Research,
https://doi.org/10.1007/978-3-031-44792-1_8

8.2 Conceptual Framing

We report on a study that is part of a larger project funded by the Institute for Research in Schools (IRIS) in the UK to explore school students' views related to science, their reasons for participating in IRIS projects, their views of these projects and their views about wider aspects of why students do or do not engage in IRIS projects, and what they have gained from their experiences. We focus on our analysis of qualitative data gathered from student interviews. Our specific research question is: 'How do secondary school students who are participating in a biology research project see both science and themselves in relation to it?'

Our research question was chosen because of an increasing recognition among science educators of the value of considering issues to do with students' science identity and their perceptions of science when researching students' responses to school science (e.g., Holmegaard & Archer, 2022). Aspirations and choices can involve identity, as ways to convey who someone is or who they want to become, and/or to undertake personally meaningful, interesting, and enjoyable activities (Holmegaard et al., 2015). Contemporary models of science identity highlight the relevance of someone recognising themselves and also being recognised by others as being a science person; someone may enact or embody a particular identity through undertaking particular practices or performances, which require specific knowledge and skills, and which are recognised by others (Carlone & Johnson, 2007). Wider analytical and theoretical frameworks also highlight the relevance of intersecting personal and socio-cultural aspects, such as finding science interesting and enjoyable (Avraamidou, 2020). Identities can change and develop over time; resources, contexts, and/or experiences can facilitate or limit some developments, and further experiences can be sought or avoided, through various trajectories (Gonsalves et al., 2021).

8.3 Materials, Methods and Analysis

The data used in this paper were taken from the qualitative phase of the larger study outlined above. Interviews were undertaken with participants between the ages of 12 and 18 from eight schools in England (seven state schools and one independent school). Thirteen of these students were undertaking biology projects and it is these thirteen interviews that are analysed here (nine from the state schools – three from one, two from another, one from each of four and none from one – and four from the independent school). All the participants undertook a scientific research project through IRIS and volunteered to take part in our study. We had no role in the design or undertaking of the projects. Examples of projects included mapping UK trees and investigating the impact of climate change, synthesising DNA, exploring how a reduction in diversity affects humans and other animals, and analysis of biological material using a scanning electron microscope. Information sheets (explaining the purpose of the research) and consent forms were sent to the schools to be distributed to potential participants and completed consent forms were obtained from the parents and the students whose data are used here. The participants' schools represented a wide coverage of geographic (urban and rural) and socio-economic background. One was in the north of England, two in the midlands, one in the northwest and four in the southeast.

Individual semi-structured interviews were conducted in the summer of 2021. Each interview lasted between 20 and 30 min and was directed by an interview agenda that was based on the research question. Initially, we had hoped to conduct face-to-face interviews. However, due to COVID-19 restrictions in place at the time, all the interviews were undertaken using the online platform Microsoft Teams. Although this approach provided reliable data on students' views about science and investigative research projects, it was not without obstacles. For example, in a few of the interviews the internet connection was unstable and consequently a small proportion of the respondents' replies were lost. In addition, in response to their school's safeguarding policy some of the participants chose not to turn their camera on during the interview. In such cases it was not possible to capture any non-verbal communication. All interviews, with participants' permissions, were audio-recorded and transcribed verbatim. Names of the participants cited in this article are all pseudonyms to protect participants' personal identities.

The interview responses were analysed following the approach to thematic analysis outlined by Braun and Clarke (2006, 2021). This approach has been widely recognized in qualitative research for its flexibility in not only developing significant themes from raw data but, as Boyatzis (1998, p.xiii) argues, in allowing for "meaning to be articulated or packaged in such a way, with reliability as consistency of judgment, that description of social 'facts' or observation seems to emerge". In this sense, thematic analysis echoes the general underpinnings of 'grounded theory' as articulated by Glaser and Strauss (1967), in which the central themes are developed in the actual data collected.

The students' responses were first read repeatedly and discussed by the first and second author to familiarise ourselves with the data, in line with Braun and Clarke's (2006) recommendation that researchers become intimately familiar with their entire data set since this lays the foundation for subsequent steps. Preliminary themes that we found relevant to our research question were identified by the first author. The relationships between these preliminary themes were given careful consideration by the first and second author. In this way, we were also able to identify features of the interview transcripts that required further probing and collapse some of the preliminary themes into new ones, thus reducing their overall number. As new themes were developed, participants' responses were re-read to check that the new themes validly represented the interview data. Towards the conclusion of the process, no new themes arose, which indicated that the most important ones had been identified.

We identified the following six themes, which are discussed in the findings section: motivation for participating in the project; benefits of participating in the project; views about science; views about school science; science aspiration; and family involvement. As is usual, we do not claim that another group of researchers would necessarily (or even probably) arrive at the same themes; there is an element of subjectivity in thematic analysis, though we tried to be as objective as possible.

8.4 Findings

8.4.1 Motivation for Participating in the Project

The findings suggest an association between the participants' motivations for engaging with the IRIS investigative research project and their science identities, with many of them articulating that participating in the project provided them with an "authentic" experience of what "real scientists" do. For example, John expressed that:

> For me, it's an ideal way to say you have actually had exposure to the type of equipment scientists use in the lab. This makes you feel like a real scientist, which you don't get when you do school practical.

Sarah, who, wasn't yet involved in an IRIS project, but intended to do one next year, when asked "so, what is motivating you to want to do the IRIS project?" replied:

> It is just because I am interested in it because I don't have a lot of chances in school or in my personal life to get very involved in any research projects. IRIS does provide a way to looking into researching and STEM and I find that very fascinating.

When Sarah was then asked "so, do you think the IRIS project will give you a better idea of what doing science or being a scientist is?", she went on to say:

> I think it does, especially the research and report and the presentation parts of it because you have to carry out your own research and you have to come up with really valid conclusions and I would think that's what real scientists do.

For a number of students, it seems that participation gave them an opportunity to understand themselves as scientists. They felt that by actively working with practising scientists they had a more representative experience of the processes of science and had become more socialised into the discursive practices [our phrase] of the science community. For example, Nara highlighted her work in using data to evidence the environmental changes in Antarctica. For her, the project not only informed her understanding of the extent to which human activities contribute to climate change but, as she put it, "provided real opportunities to engage in discussions and debates about scientific issues". These experiences reinforced Nara's conception of what a scientist does.

8.4.2 Benefits of Participating in the Project

Evidence from the interviews suggests that participating in the IRIS project increased the students' interests and attitudes towards science. For most of them the project was "engaging", "exciting", "quite interesting" or "refreshing". Participants' enthusiasm about participating in a project increased when they presented their findings at an IRIS conference and received feedback from peers and members of the science community. For example, Andy said:

> When I partook in the IRIS conference, I started to understand science and my world better, so obviously before I liked science but wasn't entirely sure how it applied to the world. I had a rough idea but obviously wasn't partaking in any research projects and when I partook in my first research project with IRIS I started to understand, and it really opened my eyes to how it can be different.

As highlighted above, self-efficacy can be seen as a powerful tool to comprehend and reinforce students' motivations to learn science. In other words, a student's self-efficacy will influence their attitude and tenacity to tackle problems they encounter in science classrooms. The interview data indicates that participating in the research project increased the students' self-efficacy. For example, Michael, who said that he had always struggled with biology, now said that he no longer found the subject difficult but was intrinsically motivated to succeed.

The participants valued the experience of working in a collaborative context, which they recognised as not just an important benefit of participating in the project but an important practice in the science community. Such collaboration was seen by the participants as a means for creating new forms of knowledge, negotiating meaning and developing new skills. Sarah, who hadn't started her own IRIS project yet but got involved in a friend's project on composting, said:

> Well as we saw from the pandemic working in a group is important for science. Scientists need to share their ideas with each other. So, working in a team with people I have never worked with before was really nice to do, and although we had disagreements it really deepened our friendships. Some of the people in the group knew a lot more than me so I learnt a lot about science.

Michael said:

> Working as part of a team and discussing scientific ideas allowed me to develop my reasoning skills, and I've also learned how to take on feedback from people and also include the feedback in my work and use what peers have taught me.

One student, Pat, who conducted her own independent research, spoke enthusiastically about the skills she acquired from participating in the project. Planning and designing her research provided her with opportunities to develop reasoning and thinking skills; however, she lamented the lack of collaboration with peers, which she thought would have brought different perspectives to the process.

For some participants the project not only helped them experience some of the practices of the scientific community but gave them a deeper understanding of the nature of science – that science is tentative, and inquiry-based:

> … I think that IRIS actually helped me learn science. While doing the project I started to understand science and my world better so obviously before I liked science, but I wasn't entirely sure how it applied to the world. (Andy).

For some of the participants, engaging in investigative research projects afforded them opportunities not only to develop their scientific inquiry skills but also to acquire a deeper understanding of the epistemological dimensions of science and its connection with historical, cultural and social values. This greater appreciation and insight into the nature of science increased their science-related career aspirations, as illustrated by Nara:

> Doing the project gave me a better understanding of the subjective nature of science and how our personal view can influence the scientific process. It was exciting working with students from different backgrounds and this has reinforced my passion for science and biology especially.

Although there were varying views amongst the participants, there was broad agreement that the project gave them the opportunity to apply their scientific knowledge and engage in critical thinking, which they thought was an important characteristic of real science. Taken from this perspective, the IRIS project was generally felt to be quite different from school science. As George said:

> It's different from what we have done in the average science … with science at school it's just we get told to do this and that and then we just have to try and work it out … and like with the DNA, err the DNA project, we've like really had to think about how we're going to do this and how we're going to do that.

There was also broad consensus that participating in the IRIS project gave them a better idea of doing 'real' science or what it meant to be a scientist:

> So, I would say it's probably a reflection of real science more than it is the academic subjects. I think practical things are a massive part of science and something I don't think is reflected enough and working with samples and stuff like that, I think it's been nice to see what things are actually like ... (Michael).

Finally, some students talked about how undertaking a project helped them develop certain 'soft' skills, for example:

> It allows you to like work as a team, 'cos if someone's fallen behind and struggling you can go over get help off them or go over to someone get help or help someone yourself if you're further ahead. (Cameron).
>
> I've developed definitely, obviously, teamwork skills, and I've also learned how to take on feedback from people and also include the feedback in my work and use what peers have taught me and also my friends and things from the club and put it into my own work. (Nara).

8.4.3 Views About Science

Throughout the data, statements by the participants suggested that they held favourable views about the benefits of studying science mainly because of its perceived utility both at an individual and collective level. For many, the value of science lies in its ability to provide relevant real-world applications and a means of explaining and understanding the nature of the universe. For example, Paul said "Science can help us learn lots of information and people are still discovering information, for example, COVID-19. We need science to develop vaccines to help come up with statistics that help the community try to reduce the number of cases". In answer to the question "In what ways do you think science is beneficial for life or for the wider society?", Peter replied:

> It's kind of the answer to the future. I don't think that there is any other kind of special area which could, well, there isn't, progress humanity as a whole and propel our development.

> So, I suppose you could say that science and innovation are, for the minute, the most prominent things that need improving. Science is how the world works and I think it can influence our society in terms of the social aspects and it also plays a big role and science can change so many different areas, like the environment, for example; that's the big thing at the moment and science is the core of everything that people discuss about the environment.

For some participants, the perceived utility of science seems to operate at multiple levels. Not only did they see the value of studying science as a way of understanding the universe but also in relation to their own goals or career intentions. Michael wanted to go into medicine but also said:

> I think with medicine, you have to have a back-up plan … backup in biochemistry and that is going to be my backup. I mean, that's like an ideal way to say you have actually had exposure to the type of equipment and I know how to use this and look what I have studied and look at the things that I got from and stuff like that.

For some of the participants, there seems to be an awareness of the importance of scientific evidence in shaping public policy. For example, Peter said:

> Science is how the world works and I think it can influence our society in terms of the social aspects and it also plays a big role and science can change so many different areas, like the environment for example; that's the big thing at the moment and science is the core of everything that people discuss about the environment.

8.4.4 Views About School Science

Although most of the participants held favourable views about science, many of them did not view school science as comparable to the science practised by scientists in the wider world. This was illustrated by Peter who expressed:

> [School science] lacks sometimes the experience that you'd require for actual science work; there is that odd occasion when we do a project that is quite similar to the work that a scientist actually does, so it is quite useful sometimes, but other than that, sometimes it kind of lacks in that experience.

Some of the participants felt that school science was much too influenced by the National Curriculum and consequently was much too prescriptive with, normally, no opportunity to undertake investigative research projects. As Helen put it:

> We are preparing for A levels, and we only learn what is in the GCSE specification. We hardly do any practicals … we just spend most of the time remembering lots of information for the exams.

A few of the participants, however, felt that school science was similar to 'real science' since it offered opportunities for students to develop a repertoire of scientific practices. When Michael was asked "So, what do you enjoy about doing school science?", he replied:

> I just like the idea that there's always an answer, well most of the time, and I sort of like the scientific way of working with things, I like working logically. I think a lot with non-scientific subjects, it can be going all around the bend and you might not even get there. I

> like the logicality and I like the systematic sort of process of everything and I think that's just the way my brain works.

Moreover, some students felt that school science allowed them to participate in scientific inquiry through which they could learn skills that scientists use in their day-to-day practice. When John was asked "Do you think that science at school is similar or different to what scientists do?", he answered:

> I think that at this school, with the labs, yes. You get an opportunity to see what it's like to work in a real lab because it's all student-led. We have to take on our own roles and responsibilities so I think in our school, it's quite similar to a real lab.

At the same time, some of the participants acknowledged the importance of school science in providing a foundation to build on:

> I think every scientist will have started by having a key understanding of science, that basic level of what we teach in school, and they then use those key skills to develop things in the wide world, so I think everyone needs the understanding of science from the core. (George).

8.4.5 Science Aspirations

Many of the participants during the interviews expressed that exposure to investigative research projects positively influenced their aspirations and career choices:

> Yes, definitely … it's shown me what scientists do and it has shown me how fun it is and how enjoyable and how much I would like to actually do that as a job in the future and so definitely it has influenced that. (Jasmine).
>
> … I didn't think about becoming a scientist before, I was pretty much focused on becoming a lawyer but now that I did the project, I started thinking well maybe I could become a scientist. It seems like a very cool field to work in. (Helen).
>
> I think I have gained a better understanding and a better willingness to attempt new things. I am not going to just isolate myself into focusing into one area in science but I am going to look furthermore into the field of science. (Shane).

8.4.6 Family Involvement

Most of the participants felt that they were well supported by their family not just in their education and learning but in the active encouragement they received to do science. This, in part, may have accounted for their positive attitude towards science and motivation to participate in out-of-school related activities, such as IRIS:

> … from a young age because my parents are math and science-oriented people, they encouraged me down the science and math path. (Sarah).
>
> My mom thinks that I will be really good at science and encourages me to get involved in science activities to discover new stuff, especially in the environment. (Michael).

Moreover, many of the participants also reported that they regularly engage in family practices that support their interest in science. Such practices include debates around controversial scientific issues, watching science documentaries, and visits to outdoor science learning centres:

> My family is very interested in going to lots of science museums and the exhibitions, planetarium, and lots of science-related activities I was interested in. (Michael).

Notably, participants from families with 'high' science capital were more likely to be encouraged to continue studying science beyond the compulsory years and to pursue careers in science or science related fields. Nara talked about how all four of her grandparents are doctors "and they also helped me become interested in science along the way". She went on to say:

> My mom was really interested in science when she was at school and so was my dad and when they learned that I was really interested in science they were really happy and they encouraged me to join IRIS as well, so yeah, they really like it … the Science Museum is definitely somewhere we would go a lot and also I think I went to the Big Bang Fair, two years ago or something; we went there as a family, and it was really fun, in particular the planetarium … definitely, I'm interested in STEM and subjects surrounding that so I think a career in science would be really fun.

8.5 Discussion

It is clear, in response to our research question, 'How do secondary school students who are participating in a biology research project see both science and themselves in relation to it?', that many of the students felt that their participation in an IRIS project had changed how they saw both science and their relationship with science. Participants were strongly positive about the benefits of participating in such projects. Implicit in a number of the participants' statements above is a conceptualisation of learning science as an acculturation process in which learners develop science process skills by engaging in conversation about science. In this sense, as Lave and Wenger (1991) articulate, for learners to progress they much submerge themselves in the social practices of the community, guided by the expertise of more knowledgeable others who are skilled in their craft. Moreover, Brown et al. (1989) argue that learners are better able to acquire the knowledge and skills of science when they not only observe existing practices but become 'full participants' in the science community and its discursive practices.

Furthermore, an extensive body of critical scholarship has pointed to an increasing and worrying lack of interest among students in studying science at upper secondary school and aspiring to careers in science and related fields (see, for example, DeWitt & Archer, 2015). While we would argue that there are many factors that may relate to students' lack of interest (including home background, gender and ethnicity), recent research has identified an association between students' interest and engagement in science and pedagogical approaches that teachers' employ (Puslednik & Brennan, 2020). Both tacit and explicit statements from the participants seemed to reaffirm Pusldnik and Brennan's (2020) views that exposure to investigative research projects positively influenced their aspirations and career choices, though it could be argued that since participation in the projects was voluntary, the interviewed students may have already had high aspirations towards science-related studies. Nevertheless, such findings illustrate the pedagogical value of investigative research projects in mediating science learners' orientation towards careers in science, especially those from underrepresented backgrounds.

At the same time, we acknowledge that we have no longitudinal data as to the long-term effects of participation in these projects. Further research on such long-term effects seems warranted, given the frequent enthusiasm exhibited by the interviewees in this study of their participation in investigative biology research projects.

References

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*(14), 1945–1969.

Avraamidou, L. (2020). Science identity as a landscape of becoming: Rethinking recognition and emotions through an intersectionality lens. *Cultural Studies of Science Education, 15*, 323–345.

Bennett, J., Dunlop, L., Knox, K. J., Reiss, M. J., & Torrance-Jenkins, R. (2018). Practical independent research projects in science: A synthesis and evaluation of the evidence of impact on high school students. *International Journal of Science Education, 40*, 1755–1773.

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Braun, V., & Clarke, V. (2021). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology, 18*(3), 328–352.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–41.

Carlone, H., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education, 37*(13), 2170–2192.

Gatsby Charitable Foundation. (2017). *Good practical science*. Gatsby Charitable Foundation.

Glaser, B., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine Publishing Company.

Gonsalves, A., Cavalcante, A. S., Sprowls, E. D., & Iacono, H. (2021). "Anybody can do science if they're brave enough": Understanding the role of science capital in science majors' identity trajectories into and through postsecondary science. *Journal of Research in Science Teaching, 58*(8), 1117–1151.

Holmegaard, H. T., & Archer, L. (2022). *Science identities: Theory, method and research*. Springer.

Holmegaard, H. T., Ulriksen, L., & Madsen, L. M. (2015). A narrative approach to understand students' identities and choices. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education* (pp. 31–42). Springer.

Kampourakis, K., & Reiss, M. J. (Eds.). (2018). *Teaching biology in schools: Global research, issues, and trends*. Routledge.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Puslednik, L., & Brennan, P. C. (2020). An Australian-based authentic science research programme transforms the 21st century learning of rural high school students. *Australian Journal of Education, 64*(2), 98–112.