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# **Integrating Research and Knowledge Exchange in the Science Undergraduate Curriculum: Embedding Employability Through Research-Involved Teaching**

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Additional information is available at the end of the chapter

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## **Abstract**

The aim of this chapter is to give an overview of how engaging undergraduate students with research and research-related activities can be used to enrich their learning experience and enhance their employability prospects. There are two specific challenges in producing industry-ready science graduates: providing students with relevant subject specific and transferable skills and knowledge, and to provide them with appropriate industry engagement. The science undergraduate curriculum at Canterbury Christ Church University (CCCU) includes research activities that are designed to move students from being recipients of knowledge to becoming collaborators in its production. This approach to “research-involved teaching” (RIT) provides students with opportunities to gain practical research experience through course-based undergraduate research experiences (CUREs) and individual undergraduate research experiences (UREs). Students on the CCCU science programmes are diverse, many coming from low-participation neighborhoods and/or with nontraditional entry qualifications who have taken up study via the Foundation Year in Science (pre Higher Education level) that can be taken as part of each of the science programmes. Such students in particular can benefit from RIT. This chapter briefly summarizes the development of undergraduate research in higher education and then presents examples of specific pedagogic interventions, CUREs and UREs used across the CCCU science programmes.

**Keywords:** employability, undergraduate research experience, research-involved teaching, enquiry-based learning

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# 1. Introduction

## 1.1. The “research-teaching nexus”: are research and teaching two sides of the same coin?

Until the nineteenth century, teaching was considered to be the primary function of universities [1]. In the West, the view that research should become part of the purpose of universities was first articulated and implemented in Europe, specifically in German universities:

“... universities should treat learning as not yet wholly solved problems and hence always in research mode.” Wilhelm von Humboldt on the future University of Berlin (1810), cited in Ref. [2, p. 110].

The ideal of universities as institutions of learning, teaching *and* research spread to the US and elsewhere in the late nineteenth and early twentieth century [3]. Academics in higher education began spending increasing proportions of their time researching. Henceforth, it was commonly assumed that teaching and research were mutually supportive activities and that the expertise and insight gained during research improved learning and teaching quality for students [4]. A number of putative relationships between teaching and research were consequently proposed and described using various terms and definitions [5]. A useful and inclusive term that describes a range of modes by which students interface with research in their learning and development is that of the “research-teaching nexus” [6, 7]. According to Haslett [8]:

“The positioning of teaching within the nexus is determined by the role students play (i.e., students as research participants, or as an audience for research) in relation to the research emphasis (i.e., emphasis on research content or on research processes and problems). The nexus has proved useful to institutions and academics in helping them strategically consider the links between research and teaching in their own curricula and teaching.” [8, p. 1].

Initially, the mutualism between teaching and research in the “research-teaching nexus” seemed self-evident: academic researchers bring their critical and reflective approach to their discipline and their hands-on experience of research methods and professional communities into the classroom, acting as a prism through which students are exposed to research in all of its many facets. Moreover, there was an assumption that research active staff aware of the current developments in their field would be able to enhance their student’s learning experience. However, several authors have since challenged this relationship as one that remains unsubstantiated by research and scholarly evidence [9–11]. Indeed, comprehensive analyses of available data show that the quality and/or quantity of research output of a lecturer does not correlate strongly with undergraduate students’ perception of teaching quality [9–12]. Undergraduate students do report, however, that being taught by active researchers can enhance their engagement and experience at university [13]. This indicates that teaching quality and student learning are not *necessarily* improved by the research activity of the teachers themselves via a passive mechanisms of osmosis, but rather that students must be actively involved in research to create learning experiences that go beyond those typically understood to be part of the “research-teaching nexus” to create what we will here refer to as “research-involved teaching” (RIT). Directly involving students in research-related activities—if done effectively—can result in a number of reported benefits to their development of scientific skills and knowledge as well as their confidence in carrying out research [14, 15].

## 1.2. Teaching in higher education and the role of undergraduate research: one goal, many approaches

Undergraduate research and inquiry can be defined as “student engagement from induction to graduation, individually and in groups, in research and inquiry into disciplinary, professional and community-based problems and issues, including involvement in knowledge exchange activities” [16, p. 16]. In this context, Linn et al. [17] distinguish between more individualized and bespoke “Undergraduate Research Experiences” (UREs) and “Course-Based Undergraduate Research Experiences” (CUREs; see also Ref. [15]):

“UREs feature individual students in faculty research laboratories and provide the opportunity for one-on-one mentoring. Typically, students spend one or more semesters in labs, although the type of activity and form of mentoring varies substantially [...]. In contrast, CUREs have a curriculum and are open to most students. CUREs put high demands on mentors to guide many students.” [17, p. 2].

Typically, UREs (e.g., research internships, work placements, etc.) are bespoke and individualized research experiences that affect only a few students and that can be highly competitive because of the limited availability of URE opportunities at any given time. The time invested by students in this type of experience is often high and, because of the resources and time required for delivering UREs, in many cases falls outside their regular taught curriculum (e.g., summer term breaks). The comparatively large amounts of staff, space, and material resources required for the delivery of individualized UREs (especially in applied scientific disciplines) that often require one-to-one research supervision make large-scale provision of UREs impractical at even the most research-intensive institutions [17, 18]. In contrast, CUREs are embedded in the regular curriculum and therefore open to all students of a module/programme, while at the same time being much less individualized, less resource intensive and therefore typically easier to deploy [17].

Though assessing the impacts of direct research experiences on student outcomes is challenging and has not been a regular feature of deploying interventions to facilitate UREs and CUREs [17], the available evidence suggests that engaging undergraduate students in research activities improves student engagement and retention and can attract students into postgraduate research careers [15, 18–23]. These benefits have led to calls for expanding RIT in various forms in undergraduate teaching both in North America and Europe [24, 25].

Women and minority undergraduate students seem to particularly benefit from research experiences [26, 27]. This is encouraging in light of student populations in the UK and worldwide tending to become more diverse in both social background and academic ability as higher education becomes more inclusive [28, 29]. The data also suggest, however, that the students who mostly benefit from undergraduate research opportunities are those who already have a high level of engagement and interest in postgraduate research [15, 22]. We therefore argue that a central aim of involving students in research (and of teaching in general) should be to provide opportunities precisely for those students who are not already enthused and determined to embark on research careers.

Thus, for RIT strategies to ultimately deliver benefits for all students, they must be integrated fully into university teaching programmes and curricula with forethought to maximize their impact [15, 23]. This is particularly important considering the potential cost of investing in RIT strategies at a time of increased marketization and cuts to funding in higher education [30]. Innovative models have been developed for feasibly delivering and assessing the impacts of CUREs and UREs on a large scale in high-subscribing higher education programmes [15, 31–33]. For example, Rowland et al. [34], in recognition of the importance of student choice and the diversity among participants in higher education, created a two-stream undergraduate chemistry module. One stream provided a traditional learning experience in laboratory techniques and methods and the other offered students with a desire to carry out research the opportunity to do so by carrying out a scaffolded undergraduate research project in the laboratory instead [34]. Though they identified challenges to staff and resourcing in providing and supervising a large number of undergraduate research projects, the authors found streaming the teaching better supports students with diverse needs [34]. Desai et al. [18] approached the issue of limited resources differently: they devised a tiered supervision system based on the concept of a “research-intensive community” (p. 137) at Texas A&M University. The system allowed efficient small group supervision of the research activity of undergraduate students.

CUREs can be used to provide research-involved experiences for most or all students [17]; where provision of UREs is limited, all students should be given an equal opportunity to compete for these opportunities and benefit from them even if they are not directly involved. While models for involving undergraduate students in research continue to be developed for individual learning experiences, curriculum elements, and modules, the greater challenge is to develop undergraduate research opportunities across entire undergraduate curricula and programmes that are interlinked and build on each other throughout the student journey. Moreover, involving undergraduate students in knowledge exchange and collaboration with researchers in industry and elsewhere outside of the university in the context of research has not received as much attention as involving students in institutional academic research. All of these aspects of student development are essential, however, for developing research-ready graduates that have the skills required by employers who hire graduates [35].

### **1.3. Undergraduate research improves undergraduate employability**

Employability encompasses what graduates know, what they can do, their job specific skills, their transferable skills, and their attitude and behavior [36]. The required skills are often specific to an employer or specific sector of the economy [37]. Graduates, especially from biological science programmes, therefore enter into a highly competitive job market where research skills are often critical to prospective employers. A recent consultation undertaken by the Association of the British Pharmaceutical Industry [38] identified that graduates often lack the required skills or knowledge important for employment within the life science industry and that newly employed graduates routinely need extensive graduate training, which can represent a major commitment from the employer [39]. This skills gap can be significantly reduced, however, where there is suitable employer engagement within the degree programme. For example, the involvement of Siemens with the University of Lincoln engineering degree has allowed Siemens to reduce the length of

their graduate training programme by 9 months [40]. A key element of higher education engagement with industry is in shaping graduate behavior and attitude such that the graduates understand their choices and employer expectations, and are positioned to meet those expectations. Two specific challenges need to be addressed to produce industry-ready graduates: to impart relevant job specific and appropriate transferable skills, including research-specific skills, and to provide the appropriate industry engagement and an understanding of the responsibilities and practice of those working in the respective industry. Involving undergraduate students in research and knowledge exchange can help meet the first of these challenges through the general benefits it provides to the cognitive development and skills development of students [41]. More importantly, however, participation in undergraduate research can break down student misconceptions about scientific research, careers in science and the day-to-day activities of research scientists [42].

## **2. The research-involved student journey at Canterbury Christ Church University**

### **2.1. An outline of undergraduate science programmes at Canterbury Christ Church University**

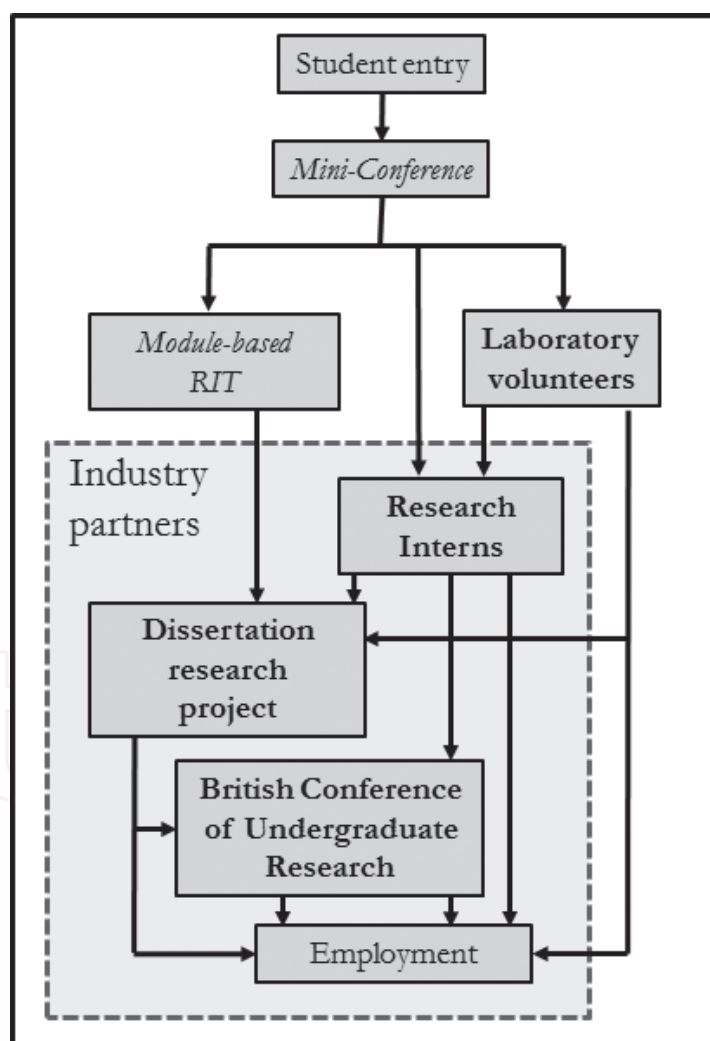
The Section of Life Sciences at Canterbury Christ Church University (CCCU) in Kent, UK, currently delivers eight undergraduate programmes (3-year BSc programmes Honours in Bioscience, Biomolecular Science, Animal Science, Plant Science, Ecology and Conservation, Environmental Science, Environmental Biology and Integrated Science) that can also be taken as joint-Honours programmes with other disciplines, such as Sport Science or Forensic Investigation. In addition, all eight programmes can be taken as 4-year programmes with an additional Foundation Year (which is shared among the programmes) that is designed to maximize inclusivity of all programmes and therefore has no entry requirements. The Foundation Year traditionally recruits students from highly diverse backgrounds, including mature students, students who have taken alternative routes into higher education and students who are from areas with low participation in higher education. Currently there are 500 students enrolled in the undergraduate science programmes at CCCU. Full-time undergraduate students in the biological sciences at CCCU are more likely to be from underrepresented groups in terms of gender (44% male students at CCCU versus 35% nationally), nonwhite ethnic groups (26% versus 19%) and reported disabilities (18% versus 10%) [43].

The teaching staff in the Section of Life Sciences currently includes 20 academic staff, 7 university instructors (part time PhD students with teaching responsibilities), 2 postdoctoral teaching fellows, and 8 technical support staff. All of the academic staff, university instructors and postdoctoral teaching fellows are active researchers. The staff is also highly multidisciplinary in composition, with 12 biomolecular scientists, 6 ecologists, 4 physicists, 3 chemists, 2 bioinformaticians, and 2 plant scientists. The learning and teaching in the Section of Life Sciences at CCCU is informed by the University's Strategic Framework 2015–2020, which calls for “the integration of excellent teaching, research and knowledge exchange” as one of its core values [44, p. [2]. The teaching staff share a vision of a curriculum with a strong focus on involving students in research and knowledge

exchange to enhance their critical thinking abilities, subject specific skills, and employability prospects. The programmes the Section delivers are therefore designed around RIT and high-impact pedagogies to support the development of “student researchers” and provide students with a range of research opportunities and research-like experiences through CUREs and UREs.

## 2.2. General aims and features of the undergraduate science curricula at CCCU

All undergraduate science programmes at CCCU feature a high proportion of practical content (approximately 50% of contact hours) in which students engage in laboratory- or field-based experiments linked to lecture and seminar content. Research-like experiences feature from very early on in their student journey as part of the taught curriculum and there are both CUREs and UREs that provide opportunities for students to participate in research throughout their studies (**Figure 1**). Most importantly, however, these research experiences



**Figure 1.** A diagram representing the various opportunities for students to engage with undergraduate research experiences (UREs; bold) and course-based undergraduate research experiences (CUREs; italicized) during their student journey through the undergraduate science programmes at Canterbury Christ Church University. The box with a dashed line circumscribes UREs in which industry partners can be involved in RIT.

are coordinated across the years of study to build upon each other and provide continuity in student research engagement. First year students are introduced to the concept of undergraduate research and opportunities for becoming volunteer researchers in the first month of their studies via the “Mini-Conference” (see Section 3.1). A research internship programme open to students in any year of study is also available (see Section 3.2). Finally, students complete their studies with a research project (see Section 3.3). Significant investment into offsite laboratory facilities has greatly expanded and strengthened the delivery of CUREs and industry-linked UREs (see Section 3.4). Research-relevant experiences are also embedded into modules through assessments, for example (see Section 3.5). A student experience summarizes the impact an integrated approach to RIT can have on the development of graduate skills and employability (see Section 3.6). It is not uncommon for undergraduate science students at CCCU to co-author publications, posters and conference presentations with academic staff in peer-reviewed journals. An annual competition is held to send one or more undergraduate students to the British Conference of Undergraduate Research to present the results of their individual UREs to an audience of their peers (**Figure 1**).

### 3. Examples of research-involved teaching activities, UREs and CUREs integrated into the CCCU science programmes

#### 3.1. The Life Sciences Mini-Conference and laboratory volunteers: an introduction to research for undergraduates

The Life Sciences Mini-Conference is part of the required curriculum for all science programmes and runs in the first week of the term in the first year (**Figure 1**). As such, it is inclusive of all students, regardless of their motivation and academic background at the time. The conference features a full day of presentations by academic staff and PhD students about their ongoing research. It is designed to immerse students in the atmosphere of a research conference: students receive a book of abstracts for the presentations and are encouraged to ask questions during and after presentations, just as they would at any other research conference. The diversity of the teaching team in the Life Sciences is reflected in the conference programme: presentations typically cover active research from ecological, molecular and physical sciences. This means students are exposed to a range of research activities and topics that they may not have previously been aware of, thereby helping them to develop interests that will inform their further choice of studies and, ultimately, their career path [41, 45]. The conference also helps students at the very beginning of their studies to associate lecturers with their research activities. Students commented on their experience of the Mini-Conference in 2015:

*“The Mini-Conference made science look exciting and helped me to pick areas of interest for the future of my degree.”*

*“The Mini-Conference gave me a first glance of the opportunities for gaining experience in science.”*

Emphasizing the research of their lecturers so early on draws a clear distinction between the learning environment students would have typically experienced at school and how it

differs from the academic environment at University. By encouraging students to mingle and converse with the presenters during coffee and lunch breaks, barriers between students and academic staff are broken down early on in the student journey, directly contributing to the “professional socialization” of undergraduates in science [45–47] and familiarizing students with the responsibilities and professional life of researchers [42].

In creating opportunities for unexpected learning and explorative discussions, the Mini-Conference is a key element in the RIT strategy. Shortly after it has taken place, all first year undergraduates are invited to attend a research opportunity briefing where lecturers share accounts of the research experiences and positive contributions made by past undergraduate researchers in the Section. The briefing is used to advertise ways in which students can get involved in authentic research on an occasional or regular basis via bespoke UREs: opportunities to work with academic staff are discussed, either on a volunteer basis or as a paid intern (through the CCCU internship scheme) (**Figure 1**). Typically, more than a dozen motivated students each year take up one or more of these opportunities, significantly contributing to their personal and professional development and employability. In its compact nature and being part of the undergraduate curriculum, the Mini-Conference is not very resource-intensive and therefore represents a very powerful CURE that links directly to recruitment of students for bespoke UREs positioned throughout the programme.

### 3.2. Student research internships as flexible and bespoke UREs beyond the curriculum

The student research internship programme offers the opportunity to further build student/staff partnerships in a scheme that co-produces knowledge via student research. Research internships are developed by academics in partnership with industry (see Section 3.4; **Figure 1**) or with student input. Available projects (typically 5–10 each year) are advertised to all students.<sup>1</sup> The internship programme is also an opportunity for students who are volunteering in research labs to concretize their research and build on the research experience already gained (**Figure 1**). Typically, internships last 10 weeks on a half time work schedule and are carried out in the summer months outside of the regular curriculum. Each student receives a bursary and is supervised by one or more researchers within the Section as well as any industry collaborators. This is feedback from student interns in 2015:

*“It was a really good learning experience. Doing something where the outcome really matters is brilliant because you’re making a difference and making a real impact on conservation research.”*

*“I really enjoyed my time working on this project. Not only did I help contribute towards the ongoing research at CCCU, but I also gained some valuable skills to add to my C.V.”*

Our partners, both in academia and in industry, are also very positive about these partnerships. Some of them (especially academic ones) may initially feel slightly reluctant about the prospect of working with undergraduate students in “real” research, which many associate

<sup>1</sup>See <http://www.canterbury.ac.uk/social-and-applied-sciences/human-and-life-sciences/life-sciences/internships/internships.aspx> for details of some of last year’s internships [Accessed January 31, 2017].

exclusively with postgraduate students. However, their feedback after projects are completed is very positive, resulting in long-lasting research partnerships involving undergraduate student researchers. Two partners who have collaborated on student research projects at CCCU stated:

*"I was really impressed with the work ethic showed by [the] students involved in the research we did together. I don't know of many institutions in which academics collaborate in research projects with undergraduate students, who then end up as co-authors on their papers. The previous project yielded two papers, and I am hopeful the current one will result in another paper in the near future." (Academic partner)*

*"[We] have been very impressed with the whole process of finding and running a student internship with Canterbury Christ Church University. As an industrial partner it was imperative that the best student was selected and that the project met the company aims. This was a very successful project due to the skills and dedication of all involved and we fully expect the results to influence tarantula taxonomy when published." (Industrial partner)*

The internships also have additional benefits related to RIT. They position students as key mediators in the flow of knowledge exchange between academic researchers and industry partners during the project [48]. If the students work with an industry partner, they also get the opportunity to experience a typical work environment, work roles and responsibilities in that industry [49, p. 82].

### **3.3. Adding value to undergraduate dissertation research projects through individuality and flexibility**

A final year dissertation research project as a conclusion to studies is a standard feature in UK Bachelor of Science programmes at the Honours level [25]. At CCCU, the "Individual Study" module in the third year of study represents the dissertation project. The module is designed and structured to act as a bespoke URE for students completing their programmes of study and a number of research skills are assessed throughout the module. Students are very flexible in their choice of projects—in principle they have the ability to choose any academic supervisor and any topic for their research project, as long as it meets ethical requirements, health and safety requirements and can be supported by the resources and equipment available. This means students are not presented with a "cookie cutter" project, but are encouraged to creatively develop and design their own research ideas in collaboration with an academic supervisor and external partners where appropriate. Students who have already volunteered in research laboratories or who have completed research internships can use this opportunity to build on their prior research and take full ownership of it for their dissertation project (**Figure 1**). Students also have to organize and go through all relevant ethical approval and health and safety assessment procedures before they can begin their study. Students then work independently in the laboratory or field to complete their projects and, as part of their assessment, produce a research logbook that meets the standards of a researcher in a professional laboratory. Communicating research has been identified as a graduate skill that is often neglected [50] and students are therefore also required to complete:

- a research paper written in the style and format required by a relevant peer-reviewed journal of the student's choice
- a 20-min oral presentation of the work

To facilitate student engagement with supervisors in a mode similar to that common in post-graduate research supervision, students are also assessed on their engagement with the project and how regularly they meet with their supervisor. They also hand in their logbook at the midpoint of the module to receive formative feedback on their progress. This module design is resource-intensive and requires individualized supervision of diverse projects that have to be flexible and extensively resourced with materials and laboratory space. The investment has benefits, however: students who design their own project are typically more motivated [51] and they can use their project to gain practical research skills as well as presentation and writing skills that are directly relevant to careers they are interested in. Consequently, some students who complete their project in partnership with an external partner are subsequently either employed directly by that partner on the strength of their project work or they can use their experience to improve their prospects for graduate employment in general.

### **3.4. The Life Sciences Industry Liaison Lab as a space for RIT informed and supported by industry**

In 2015, the Section of Life Sciences at CCCU established the Life Sciences Industry Liaison Lab, based at Discovery Park in Sandwich, UK. The laboratory has allowed the Section to extend RIT activities by establishing collaborative ventures with companies based on the Discovery Park site. This facility provides students with the experience of industry-standard laboratories, delivering student research experiences and networking opportunities through industry-based teaching, internships and placements [48]. As a result, students based at the Industry Liaison Laboratory work within a professional industrial setting, answering industry-generated questions using research-quality equipment and technology, and receiving enhanced opportunities for networking and collaboration. In addition, industry professionals and potential employers are invited to teach their specialism and act as joint supervisors on final year research projects. Some of the RIT opportunities provided by the laboratory are embedded in the taught curriculum as CUREs, others present themselves as bespoke opportunities for industry-based research projects for internships or dissertation projects (UREs) (**Figure 1**). For example, second year undergraduate students enrolled in the module "Reproduction and Development" visit the laboratory at Discovery Park to learn new laboratory techniques on the subject using the same equipment as the researchers in the laboratory. The students responded very positively to this, as reflected by this comment written by a student in the module evaluation questionnaire:

*"It was great to have the opportunity to see the reality of a functioning research lab, based in an industrial environment. This trip was also useful for students to learn about the research being undertaken here and choose a path for their individual study in their third year."*

Through the continuity in working with industry partners in Discovery Park, there is the possibility to create bespoke PhD projects funded by industry partners where students can build on research projects they initiated at undergraduate level and for which they therefore have already acquired significant practical experience.

### 3.5. Embedding research into assessment

Innovative assessment practices, which have a research-relevant component are incorporated into modules across all of the science programmes at CCCU and represent one of the elements of module-based RIT (i.e., CUREs) (**Figure 1**). Examples of this assessment strategy are a laboratory practical assessment for the Foundation Year module “Lab Skills” and a case study assignment in the third year module “Introduction to Bioinformatics”.

Foundation Year students at CCCU often have very few academic qualifications upon entry to the programme and/or have been out of education for several years. It is therefore important to gradually introduce them to the concept of working independently and allow them to develop confidence in their practical skills [14]. To this end, in one of the Foundation Year “Lab Skills” sessions, students are given a simple protocol to prepare experimental solutions under the supervision and with the support of the lecturer and practical instructors. Students obtain formative feedback on their experimental calculations and techniques during and after this session. Students are then asked to repeat the protocol the following week, this time without direct supervision or support, as if they were preparing solutions for an experiment in a research laboratory. The students submit their prepared solutions for a final summative mark based on the quality of the solutions prepared. Students are involved as partners in learning as they are also involved in deciding how the marking scheme is applied during assessment. Student feedback suggests that this assignment helps them gain confidence in their lab skills and reflect on their progress. The following are two student responses to the question “What were the best parts of the course in your view?” on the module evaluation questionnaire:

*“Assessed practical was fun and allowed us to better understand balancing equations, moles and molarity.”*

*“Doing the final assessment at the end of the year using what I learnt and to show myself how much I had progressed.”*

A different example of RIT integrated into assessment is a case study assignment for the third year module “Introduction to Bioinformatics”. Bioinformatics data (accessible from several international databases) can be searched, processed, transformed and analyzed using freely available programmes. CUREs in bioinformatics are typically not resource intensive, as a thorough research investigation can be completed within a realistic time frame on a standard computer. In addition, large amounts of biological data are constantly being generated without being fully analyzed or investigated. Thus, with careful design, students can perform novel and potentially publishable research even in the context of a single CURE assignment. The aim of the Bioinformatics Case Study assignment is for students to choose a target gene and/or taxon to study and, using sequence data available from public databases, design and carry out a piece of research to investigate a particular aspect of this gene or taxon. The vast amount of data and the enormous range of computational analyzes available means that each study can be unique. This offers great appeal to students, as they can choose a topic that they are highly interested in, such as a particular disease, organism, phenotype etc. Because of this freedom, students tend to immerse themselves more fully in their case study, developing essential skills in a range of research-relevant areas, such as study design, literature review and computational analysis. In addition, the unique and novel nature of their case study and

the subsequent interpretation of the results with the relevant literature help to develop creative and critical analysis skills [52, 53].

Assessment occurs in two parts and reflects the direct research relevance of the case study. Due to the uniqueness and depth of their investigation, students become specialists in their chosen subject, but need to demonstrate that they can communicate their research to others clearly and succinctly. Firstly, the study is written up as a short scientific paper according to the instructions to authors for the journal *Nature Communications*. The paper details how the case study was carried out, the analyses performed, the results obtained and a discussion of the results with appropriate literature. Secondly, students prepare a poster of their study to present to the rest of the class as if presenting at a research conference. Both of these elements of the assessment are designed to develop high level, research-relevant communication skills. Student module evaluations show that students perceive the case study as challenging, but rewarding in terms of the research-relevant skills obtained. This is an example quote from a student:

*"The case study was good, difficult and challenging, but enjoyable!"*

### 3.6. The student's perspective of undergraduate research

A 2015 CCCU graduate who participated in a number of the RIT activities outlined above summarized their experience of undergraduate research and the benefits it had for their career as such:

*"I am a graduate of the BSc Biosciences programme with a Foundation Year at Canterbury Christ Church University. I started university with no scientific qualifications above GCSE level, and graduated as a confident scientist. I was encouraged at various points in my degree to gain extra lab experience, and I was given the opportunity to work in a university research lab in both voluntary and paid roles during the summer months through internships. During this time, I was taught all the basic skills I needed to use in research. My supervisor dedicated a great deal of time to making sure I understood all the experiments and why I was doing them, and made sure my contributions were acknowledged on conference posters – a great thing for my CV! Having worked in the lab during the summers I decided to pursue the same area of research for my dissertation. Learning research techniques as well as experimental design led to me being offered a job in a commercial research lab when I graduated. I hadn't realized how valuable my set of skills was, and I was given a lot of responsibilities in the lab because I was able to demonstrate a good understanding of how research labs work. I was well equipped to start working independently early on and was introduced to a range of research methods, most of which I have been required to use since graduating."*

This and other students' experiences highlights the importance of providing continuity and linkage of UREs and CUREs throughout a curriculum or programme to provide students with experience of the transferrable skills that are best learned by participating in research.

## 4. Conclusion—the way forward for undergraduate research in higher education

Higher education provision in the UK and across the world is facing a number of challenges to which involvement of undergraduates in research may provide solutions [54]. Enhancing

student learning through research and providing undergraduates with research experiences prepares them for increasingly complex careers requiring research experience or transferable generic skills best acquired through research [55]. It is apparent, however, that more resource-intensive individualized research experiences delivered via UREs give a better and more complete representation of research activities [15]. At the same time, universities in most countries are facing public funding cuts and an increasingly competitive and inclusive higher education environment, resulting in a trend toward economizing teaching by delivering less resource intensive education to larger numbers of students (for example via online course delivery). This presents a significant challenge: how can impactful and meaningful RIT be developed and incorporated in curricula for larger numbers of more diverse students without significantly increasing the required resources?

The RIT strategies at CCCU described in this chapter are obviously not exhaustive and there are numerous examples of other CURE and URE models (e.g., Refs. [18, 33, 34]). In addition, a separate issue not addressed here is that of measuring the concrete benefits to students engaging in RIT and how to use that information to optimize its delivery [17]. However, the examples provided here give an impression of how low-cost CUREs like the Mini-Conference and research-relevant assessment can be linked to UREs within programmes and curricula to provide a pathway for students to engage with research throughout their degrees, making RIT a core component of the curriculum rather than a fractured or “tagged-on” experience not integrated in the rest of the curriculum. To ensure that RIT becomes a more common and integrated feature of higher education programmes, it is essential that innovative models for CUREs, UREs are developed and—more importantly—that these models are linked together in coordinated strategies within programmes of study to maximize their power and impact in transforming student learning.

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