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# A synoptic approach to science education

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## Abstract

*The University of Nottingham's Natural Sciences degree programme is an interdisciplinary undergraduate science course. Its ethos is that big scientific challenges, such as climate change or curing cancer, can only be met by a holistic approach from the entire scientific community. The scientific response to the coronavirus pandemic is an example of this. The course has a synoptic module which aims to help students integrate knowledge from across different subjects. Further, the module seeks to train students in developing their research and employability skills through interdisciplinary teamwork. Despite its good intentions the module received strong negative feedback from students in 2018/19. They raised concerns regarding the amount of work involved, individuals not participating in group work, a lack of time and resources to conduct research, unclear assessment criteria, and project topics which were not relevant to current world issues. This feedback prompted an overhaul of the module's delivery. The project topics were revised and now address global environmental, economic and social sustainability issues using the UN's Sustainable Development Goals as a framework. Students are now given a choice of assessment tasks so that they can choose whether to conduct scientific research and write a journal article, plan scientific research and write a grant proposal, or write a policy paper to put scientific knowledge into practice. The students are encouraged to use online tools to help manage the project and this also enables staff to monitor engagement and give timely advice to individuals and groups. The assessment criteria were revised by mapping each assessment activity to the employment skills identified by the World Economic Forum. The revised module was implemented in 2019/20 and received positive feedback from students. Student attainment was also very good. The university is now planning to expand this strategy by creating similar provision for students on other science courses. The intention is for research-based education to enable closer integration of research and teaching.*

Keywords: *Interdisciplinary science, sustainable development, employability skills, research-based education, problem solving*

## 1. Introduction

A university education seeks to achieve two things. There is the acquisition of, firstly, specialised advanced knowledge and, secondly, broader skills useful for a variety of potential career paths [1]. Ideally, the complete graduate from a science course would possess the knowledge and skills to, for example, think critically and independently, conduct research, work collaboratively and communicate effectively. The challenge is how to design undergraduate courses that enable students to realise their potential and fulfil this ideal.

Changes to UK universities since the 1990's have, arguably, made this challenge harder. Firstly, an increase in student numbers has encouraged traditional teaching approaches, such as didactic lectures, which can be upscaled to larger cohorts without increasing staff workload. Secondly, courses are divided into modules which encourages the compartmentalisation of learning [2]. In addition, there is the long-standing challenge of how to turn a raw first year student into someone who can break new ground.

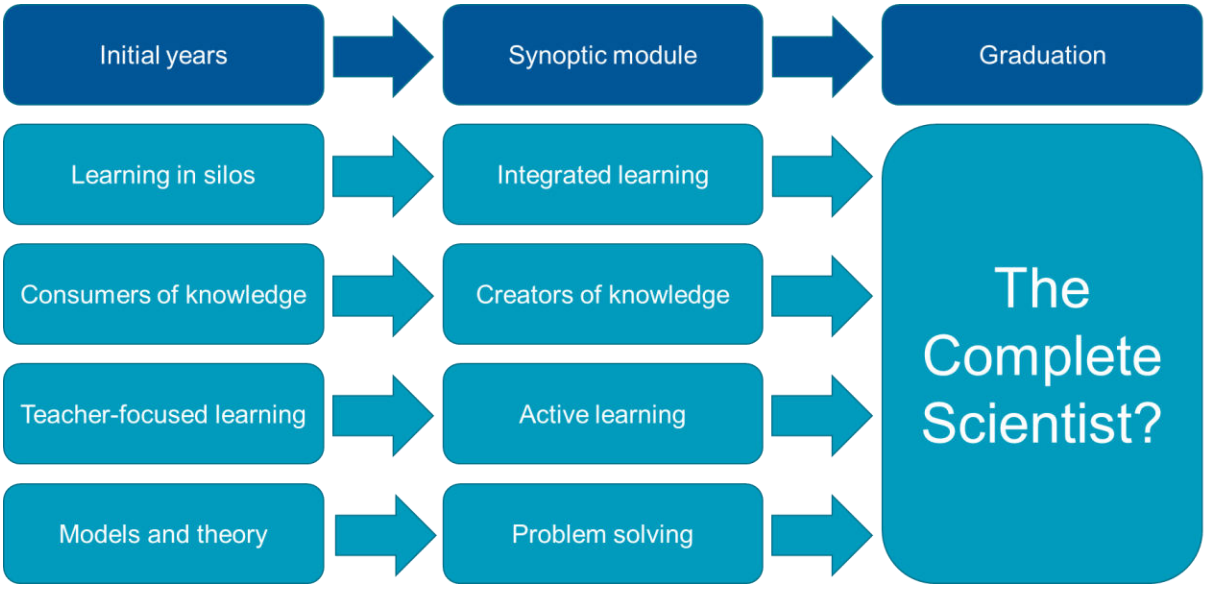


Figure 1: A schematic diagram showing a comparison of early years of undergraduate education and the Synoptic module.

In contrast to most UK programmes, students on the University of Nottingham's Natural Sciences course study multiple subjects (choosing three from Archaeology, Biology, Cancer Science, Chemistry, Earth Science, Environmental Science, Mathematics, Physics and Psychology). Despite the many different routes through the programme, students are brought together for the compulsory final year Synoptic module. This aims to be a capstone student-centred module that enables students to integrate their knowledge from different disciplines and establish new findings to solve real-world problems. However, an evaluation of the module in 2018/19 revealed strong student dissatisfaction. This unfamiliar way of working meant students were unsure what was required of them, thought the workload was unreasonable, thought collaborative group work led to unfair grading, and the science involved was mostly irrelevant. This prompted a redesign of the module for 2019/20.

## 2. Module design

The module consists of a sequence of graduated tasks to help students develop their competencies, as shown in Figure 2. The first task focuses on establishing skills for communicating science to a broad public audience. For the remaining tasks students work in groups, with each group working on a different topic and supported by a staff member with relevant expertise. The second task focuses on developing critical thinking and synthesising information from different disciplines. The third task has the greatest weighting and time allocation. Finally, each individual completes a task to help them reflect on the experience and evaluate their learning. The implementation of the design raises several questions which need careful consideration.


Figure 2: A schematic diagram of the module design showing timings, tasks and skills development.

### 2.1 What should the project topics be?

In 2018/19 there was negative feedback regarding the lack of variety and relevance of the topics to current world issues. For 2019/20 some topics were changed, and their relevance established through the UN's Sustainable Development Goals framework which encompasses economic, social and environmental issues [3]. Although science can contribute to all SDGs our projects broadly fall in to three areas. Firstly, there are projects connected with SDG 3 (Good health and well-being) advancing understanding of medical conditions such as diabetes and mental health. Secondly, there are projects connected with SDG 7 (Affordable and clean energy) investigating renewable energy sources for homes, industry and transport both in developed and developing countries. Thirdly, there are projects connected with environmental issues (SDGs 11-15) such as pollution, geodiversity and environmental management. The variety of projects ensures we cater for students with different scientific backgrounds and titles are broad, e.g. "Clean energy", to enable interdisciplinary groups to identify a niche area where all participants can contribute.

### 2.2 What should be the role of the project expert?

The module aims for knowledge exchange between researchers and students to be a two-way process. While the researcher passes on their expertise to the students, an interdisciplinary team might identify connections between subjects outside a researcher's specialised field, or they can complement the researcher's theoretical work by identifying applications and implications for policy. Staff participation is helped by the course having high entry standards, increasing the potential for high quality outcomes. Staff are deliberately titled as "expert" rather than "supervisor" because their role is to share specialist knowledge, rather than the week-to-week training and supervision which is centrally provided by the module leader. Despite this, finding staff volunteers is challenging and can limit the variety of project topics.

### 2.3 How to facilitate student research projects?

In 2018/19 every group was expected to produce a journal-style research paper. However, the intrinsic constraints of time and money limited the conduct of primary research activities. Some groups were limited to secondary research activities, such as systematic reviews, or mathematical modelling. For 2019/20, it was recognised that research skills (such as sound methodology, problem solving, advanced knowledge, understanding of complex systems) can be equally assessed by other outputs such as a grant proposal or a policy document. By choosing the submission format most appropriate to their circumstances, students gain greater freedom for the direction and scope of their research. Regardless of the submission format, all students are marked against the same marking criteria to ensure fairness.

### 2.4 How to make the marking fair and transparent?

Writing assessment criteria for an interdisciplinary context which can be implemented consistently by staff from different disciplines is challenging. In 2019/20 the assessment criteria were re-written based

on the World Economic Forum's list of core work-related skills [4]. The aim was to shift the emphasis to competencies that could be demonstrated in different contexts and use an independent source to increase the students' perception of validity. After removing irrelevant skills (e.g. physical abilities) and skills which could not be objectively measured (e.g. active listening), the remaining WEF skills were mapped against each of the module's assessment tasks and grade descriptors were written for each. As a further step to enhance fairness each assessment was double marked, including one individual marking across the different projects to ensure consistency.

### 2.5 How to assign marks to individual students?

In 2018/19 some students perceived that awarding the same grade to all group members, regardless of individual contributions, was unfair. Two changes were made for 2019/20. The first was for each group to log key decisions and achievements using a digital notebook. This provided an objective means through which staff could monitor progress and participation. The second was to include an individual reflective task which highlighted the skills acquired and provided an opportunity to acknowledge their peers' contributions. Staff could use the log and reflective task to objectively reward or penalise individual students.

## 3. Module evaluation

The delivery and evaluation of the module in 2019/20 was partly disrupted by the suspension of face-to-face teaching during the coronavirus pandemic. Student feedback was obtained via an online survey with 10 responses from a cohort of 38 students. From the beginning of the module, each group used Microsoft Teams to facilitate group discussions and document sharing. Student feedback regarding Teams was very positive: "absolutely brilliant", "massively helpful", "incredibly useful", "meetings worked well and were functional"; and meant lockdowns had little impact on student progress.

Student feedback on the new marking criteria was also positive with many students indicating it was "very clear". One student indicated they would have like more feedback and another said they received opposing comments from the two markers. Student feedback on workload was mixed. Several students commented it was "fair", "reasonable" or "appropriate" while others said "it was a lot of hard work but fair" or "more work" than other modules. When asked about the choice of projects, one student reported they "really enjoyed the topic" and another said was a "good theme and relevant to sustainability", while others reported they "would have preferred more interesting topics" or it was "so vague it didn't seem cutting-edge".

## 4. Conclusion

Delivering an interdisciplinary research module is expected to be challenging. Its ethos is new to both students and staff more familiar with modules focussed on knowledge rather than skills. However, an active learning approach that integrates knowledge from different fields to solve problems is essential for training the next generation of scientists if we are to meet global healthcare and environmental challenges [5]. In this respect, the current module design does not fully untap the potential for undergraduate students to be integrated into the research community. More ambitious concepts like vertically integrated projects would enable a broader spectrum of students to participate, tackling a wider variety of projects, to cover more of the UN's sustainable development goals [6]. The current module design also does not enable practical and specialised laboratory or field skills to be developed. However, it does provide initial exposure to the broader research process: the identification of a problem, surveying the literature, application of knowledge, and communication of science. It could be argued that all these elements should be given greater weighting in an undergraduate programme. Our plan is to introduce a similar module earlier in the course so that these skills can be developed over a longer time frame. The current module, however, provides a blueprint for how students can get a flavour of interdisciplinary research while in the controlled, safe environment of a single undergraduate module.

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