Broadening students' minds

Philip S. Lukeman and **Stefan Howorka** provide a training programme to improve the interdisciplinary breadth and depth of a nanoscience research group.

The interdisciplinary nature of nanotechnology makes high demands of research groups, and requires expertise that cuts across chemistry, physics, materials science, engineering, and biology. Maintaining a large, scientifically broad group can to some extent address this challenge, as can collaboration with external specialists. But these approaches require significant time and financial resources, and they do not translate naturally into an interdisciplinary mentality within the minds of group members.

It has been noted that students have difficulties developing an ability to think about research in an interdisciplinary manner[1]. This can hinder both the productivity and morale of a group. It can also hinder a student's writing skills and ultimately their development as a scientist. Although universities have begun to recognize this demand and some offer interdisciplinary training courses aimed at nanotechnology, graduates from these programmes are few, and their training seldom matches the specific interdisciplinary mix required for a particular research group. Interdisciplinary graduate training programmes for PhD students at the department/institute level have been proposed and implemented[2,3]. However, these are typically broad, not group-science focused, and the students do not benefit from peer-learning. The study of successful approaches to genuinely interdisciplinary graduate programmes is also still in its infancy[4,5].

We describe a training programme, initially developed in the Howorka group, that can help improve students' interdisciplinary skills. The programme can be tailored to any specific group, is easy to implement, and takes advantage of the established pedagogical concepts of peer-led learning[6]. The training has three phases.

Foundation phase. Here, the interdisciplinary syllabus of the research group is defined. It introduces subtopics to students who lack the relevant background. In essence, students run lectures for each other to cover the research area of the group. The lecture topics, selected by the principal investigator, resemble sessions of classical undergraduate courses based on basic and advanced textbook material. Example curricula are provided in Supplementary Tables 1 and 2.

Learning is enhanced by questions set by the presenting student to be answered by their peers. A subset of questions is to be answered during the lecture, while the remainder are a homework assignment. A feedback loop is set up where the presenting student grades these answers.

As the principal investigator assesses the students' questions and answers, the Socratic method — that is, prompting questions that make students clarify their assumptions, provide evidence for their assertions and ask questions about questions — can be used to refine further question and answer sessions. The principal investigator can also advise students on effective presentation habits[7]. The lecture series can be run multiple times with different yet coherent topics until the desired learning outcome is achieved.

Implementation phase 1. Here, the background knowledge is applied to interdisciplinary publications. Contemporary research papers are presented and discussed in a 'literature club' format. Students present research data from a field outside their original undergraduate training, and prepare questions about the publications to be answered at the end by their peers. The presentation, therefore, tests and applies the successful training outcomes from the foundation phase. Students are also expected to describe the interdisciplinary links that are needed to understand each paper.

Implementation phase 2. Here, group knowledge of research projects is enhanced. A student presents their own research project, with explicit instructions to utilize the depth and breadth that the previous two phases have instilled. In their presentation, research links between disciplines are highlighted, while still being accessible to a non-specialist for the respective area. If applicable, the students are also expected to make links to other research projects, or explain a specific research methodology, that has not been outlined in earlier stages.

Experience with the training programme in the Howorka group has yielded a number of positive observations. There is increased cohesiveness in the team, as students begin to learn from their peers and better comprehend the scientific basis of the projects of other group members, which leads to more productive intra-group discussions. Individual students are able to write superior first drafts of paper introductions, as they have a grasp of the wider context of their work. Students see their research from a broader interdisciplinary perspective and can more critically evaluate their experimental plans, which leads to improved research productivity.

We also expect the programme to lead to a number of additional positive outcomes. For example, the students should be able to generate original proposals more easily, and gain more from conference attendance, as they contextualize their science more deeply. The students should also be better prepared to meet the demands of employers in a range of jobs, as they have experience applying expertise to new fields. Furthermore, the approach requires the use of multiple sources and investigational techniques, peer collaboration, synthesis of knowledge, and the development of metacognitive skills; the programme is therefore an 'authentic task', as described by Brian Coppola of the University of Michigan[8,9]. By adopting this training programme (or one similar to it), we believe that all members of an interdisciplinary research group can benefit. ❐

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Additional information

Supplementary information is available in the online version of the paper.