Some Challenges for Teaching and Learning Third Level (University) Science

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1. Introduction

Based on nearly 40 years teaching science at University level, in Ugands, UK and Ireland, I want to talk about some of the contemporary challenges now facing those teaching science at third level. There have been profound changes in recent years is almost every area that impinges on teaching science at third level: in society, in science, in the students, in knowing how people learn, and in understanding the problems of teaching science. All these changes have affected what we teach and how we teach, or should have. Undergraduates are not the same as when I studied at university, or when I started teaching: it is more diverse in many ways. These changes have made the job of the university lecturer in science more difficult and in this article I want to explore some of the areas where these changes present challenges to teaching and learning science.

2. Some areas of challenge

I want to look briefly at some of the challenges that face someone teaching science at university today, although these will vary in importance from country to country, many of them appear to be of universal significance (Fig.1).
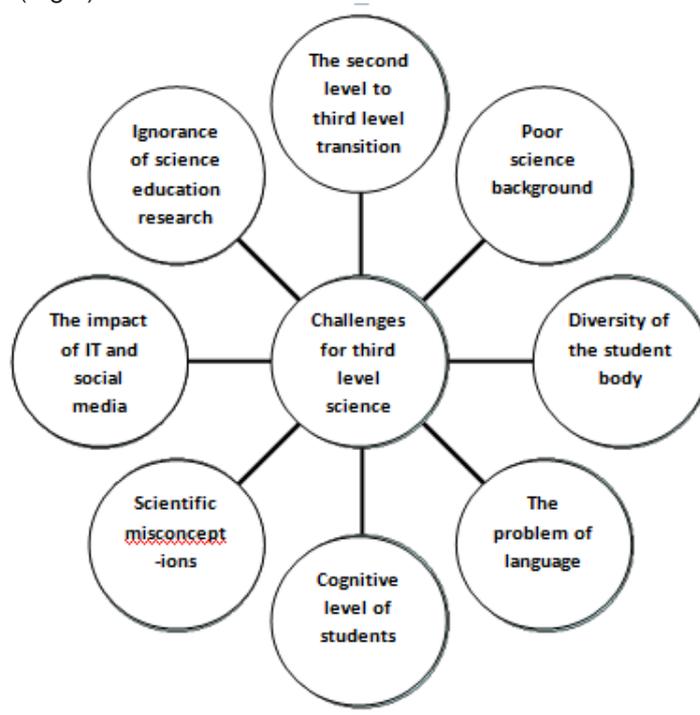
Figure 1: *Some of the factors affecting third level science teaching and learning*

2.1 The second to third level transition:

Third-level teachers often underestimate the large jump students make in moving from second to third level: there is often a major change in the academic demand; there is a change in the teaching style, and in the learning style towards more self-directed and independent learning; there is a massive social change for students as leave home for university. These changes are exacerbated if the students have average academic ability or are second-language learners (see point 2.4)). The

different expectations of students and their lecturers are not always made explicit e.g. the different behaviour required in a lecture from that in a lesson in school.

2.2 The poorer science background of students
When undergraduates were more homogeneous in background and ability it could usually be guaranteed that someone taking chemistry courses at university had studied chemistry in upper secondary school. The more diverse student background, the larger intakes and the greater range of courses available, mean that many students who are unprepared in specific science subjects. This applies to all sciences, but particularly to physics and chemistry, which are less popular at school. These students are often left behind, never understand the subject and drop out.

2.3 The increasing diversity of modern university students:
Fifty years ago less than 10% of the student cohort went on to university. In 2015 more than 50% of students go on to third level in some countries (over 60% in Ireland). The EU target for 2020 is 40% for all countries. This 'massification' of higher education has and will produce a profound change in the undergraduate body. The intake into third level now goes down to the median or below of the ability spectrum. Traditional assumptions about academic proficiency can no longer be taken for granted. This change happened earlier in the USA and they have partly dealt with the problem by having a range of types of college: two-year colleges, four-year colleges and research universities.

2.4 The problems of language in teaching and learning science:
"There are two essential pre-requisites for science education: literacy and numeracy. You cannot study any science without being able to read and write and also use numbers. These are the foundations of science education and weaknesses in either area will seriously disadvantage a student of science." [1] Mathematics proficiency is often seen as an issue for science students but the language of science is also a problem to beginners[2], and is increased for second language learners [3] or if learners with poor language proficiency. Often science is poorly understood at university because of language problems.

2.5 The cognitive level of first year students:
The university lecturer often makes an assumption that the students in front of them are capable of abstract, formal thinking. This was true when ~10% went on to third level; it is not true when 40-50% or more enter higher education. This problem was recognised 30-40 years in the USA, where the expansion of higher education occurred earlier than in Europe. Arons [4, p. 209] said 35 years ago: *".. a very large proportion of college students [25 – 75%] tend to use predominantly concrete as opposed to formal patterns of reasoning. This observation points to a profound discrepancy between our secondary school and college-level course content on the one hand, and the actual student reasoning patterns on the other".* Studies (e.g. Fig. 2.) have shown that at senior secondary or introductory college level, the **majority** of students do not function at Piaget's formal operational level.
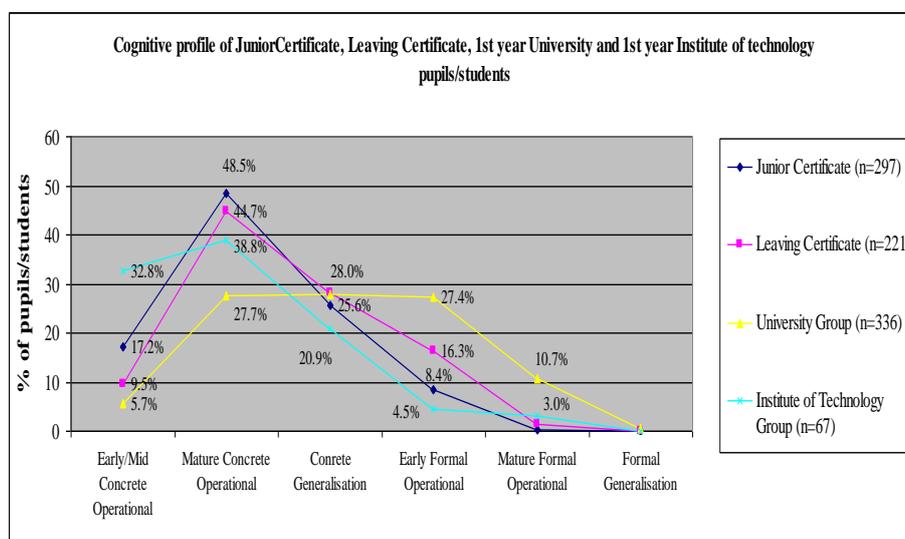

Figure 2: *The cognitive level of Irish second and third level students [5]*

Formal thinking is needed to handle abstract concepts, symbolic formulations and mathematical ideas, which are at the core of science subjects. Studies show that most of our students in upper secondary level and the early years of third level will be concrete operational thinkers.

2.6 The prevalence of students' scientific misconceptions:

Decades of research into the scientific misconceptions of second level and third level students, including student teachers, has identified, tabulated and measured the incidence of scientific misconceptions.. [6] [7] Students still enter and leave third level with misconceptions about basic scientific concepts, and we have done little to break this vicious cycle. [8] We are producing science teachers whose own misconceptions have never been challenged or replaced, and they take them back into the school classroom.

Our own work in Ireland shows that studying more chemistry at third level does **not** improve Pre-Service Science Teacher's (PSSTs) understanding of basic chemical concepts (Fig. 3). [9]
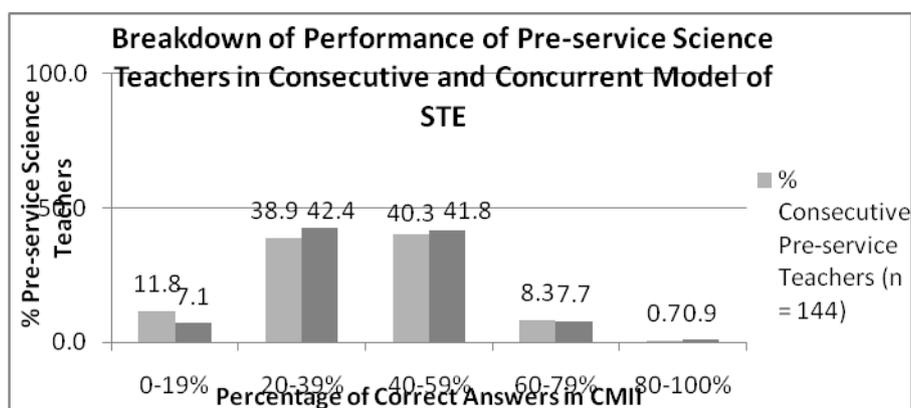

Figure 3*: Performance of pre-service science teachers on a chemistry diagnostic test. [9]*

2.7 The impact of IT on teaching, learning and course delivery:

The student body has changed in recent years with the widespread adoption of IT-mediated communication, especially smart phones and tablets, and the use of social media. Students read less and have shorter attention spans, which have had a knock-on effect in third level. The traditional lecture (50 minutes) is an alien experience for many students and does not match their own learning style. The nature of the undergraduate student body has probably changed more in the last 20 years, if not the last 10, than in the previous 200 years. Students are coming into third level with different skill sets from the traditional ones, which were the norm in the past, and they do not always match with the learning experiences provided.

2.8 The lack of awareness and interest in science education research (SER):

Much effort has gone into science education research (SER) over many decades and a vast body of literature and research evidence has accumulated. Science teachers in school and science lecturers at university are not always aware of this work or do not use it to inform their own teaching. [10] Much of the science teaching in universities is thus done in the way it was done 20, 30, even 50 years or a more ago. There is, however, much more experimentation and innovation at third level, and research into teaching and learning, than there was in previous years. This is still often confined to a few enthusiasts, mainly because teaching at university level still plays second fiddle to 'real' scientific research, which is the main criterion for promotion.

3. Conclusion

Many of the problems experienced by third level lecturers e.g. poor attendance, low motivation, high drop-out rates, are in part due to the changed undergraduate population and a failure to adapt teaching methods to this changed situation. The main problems occur in the first year when students are making the transition from second-level and it is here that intervention is needed to help weaker or less well-prepared students in making the transition successfully. There is also the argument that we should be offering different types of courses to suit the different types of student, rather than expecting 'one size to fit all' and as a consequence, 'dumbing-down' courses to fit the students. It is hard to see

how we can both broaden intake (a socially desirable objective) and maintain the same standard of bachelor degrees (an essential professional objective). Ireland has had a system running for many years whereby students from school can enter university to take a level 8, 4-year honours bachelor degree or an Institute of Technology to take first a level 6, 2-year Certificate, then a 1-year course for a level 7, pass bachelor degree and then 1-2 years to a level 8 honours bachelor degree. This academic ladder allows for different student abilities and career choices, and different exit points, while allowing students the option to reach the same advanced goal by different routes.

However, in all the areas identified above, the crucial first step for the science lecturer is to recognise that a problem exists. They should then assess the size of the problem in different areas, e.g. by using diagnostic tests [11] and then use appropriate evidence-based intervention strategies, based on science education research. [12] If we want to produce competent science teachers and professional scientists who understand their subjects in depth, then we do not have the luxury of ignoring these problems in teaching science at third level. Our emphasis should be on the quality and not just on the quantity of science graduates that our universities produce.

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