Interdisciplinarity in higher education: 
A case study of the Complexity Science DTC at Warwick

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Abstract
In recent years several new degree programmes in interdisciplinary science have been initiated on the postgraduate level. The purpose of this essay is to collect some theoretical background from the educational literature about benefits and problems in interdisciplinary teaching. Building on that we present a discussion of the achievements and issues arising in the first year of the Complexity Science Doctoral Training Centre at Warwick, concluding with some suggestions for improvement.

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1 Introduction

In recent years interdisciplinarity has become more and more important in research and as a consequence also in education and training of researchers. Besides interdisciplinary undergraduate courses a particular example is EPSRC’s recent initiative in complexity science and funding of integrated MSc/PhD programmes in that area. One of these is the Complexity Science Doctoral Training Centre (DTC) in Warwick, where I hold a joint appointment together with the Mathematics Institute. The DTC has just finished its first year and in practice we face the problem of how to teach interdisciplinary material to people with a mixed background from their undergraduate. Related is the more fundamental question ‘in what sense is it actually useful to have interdisciplinary degree programmes and how can it be done properly?’

These questions have been addressed to some extent in the literature on educational science and I will give a short account of relevant results in Section 2, together with some theoretical background. In Section 3 I will shortly explain what is meant by complexity science, introduce the DTC and summarize the practical experiences and problems, taking into account information from the students and staff. I will connect this to the earlier theoretical parts in the conclusion, resulting in some concrete suggestions for improvements of the DTC teaching.

2 Interdisciplinarity

"Any structuring of knowledge into fields or disciplines creates the possibility of questioning, altering or transcending those structures." ([1], p. 201)

2.1 Disciplinarity vs. interdisciplinarity

To clarify what is meant by interdisciplinarity we first have to understand disciplinarity. According to [1], the traditional view of an academic discipline is an area of study "with its own theories, methods and content, such distinctiveness being recognized institutionally by the existence of distinct departments, chairs, courses, and so on" ([1], p. 202). Interdisciplinarity is therefore "something which involves the relating or integrating of those theories models and contents, through collaboration between departments, staff and courses" ([1], p. 202).

More precisely, a discipline can be thought of having three main characteristics [1]: First, the content, topics or problems which are addressed; second the methodologies, techniques and procedures which are used; and third the extent of reflexive analysis within the discipline about its own nature. The third point basically reflects the status of a given discipline (such as 'revolutionary' or 'business as usual'), and is only of limited interest in terms of its definition against other disciplines. Therefore it will be neglected in the following, details can be found in [1] and references therein. In the above sense a discipline is a largely autonomous area of study, but the boundaries may be permeable and different disciplines could even overlap to some extend.

Moreover, the defining features of a discipline are clearly dynamic, since new methodologies or subject areas can arise in time. Therefore the current disciplinary structure depends on the history of how knowledge has been acquired. Since there is a certain time delay in adapting this structure, disciplines most likely reflect the status of scientific development at some point in the past rather than the present. To this extend disciplines can be seen as cultural or even
historic phenomena. A classical example is computer science arising with the fast development and increasing importance of computers in the 60s. Up to the early 80s it has been hosted mainly in mathematics departments as an interdisciplinary application, and nowadays it is a well established discipline with its own department. Similar examples are material science or more recently neuroscience, which is still in an earlier stage of development. Further features of established academic disciplines [2] are the presence of a community of scholars, a tradition or history of inquiry.

Going beyond disciplinarity one can discriminate three different approaches [2]:

- **Multidisciplinarity:** Co-existence of a number of disciplines. They are seen as largely autonomous, for example degree programmes covering two or more disciplines without any specific connections exist in particular in arts subjects.

- **Cross-disciplinarity:** One discipline peering into another. A topic normally outside a field of study is investigated with no cooperation from others in the area of study concerned, e.g. physics of music. There is rarely any transfer of methodologies.

- **Interdisciplinarity:** Involves some sort of synthesis and integration of two or more disciplines, which will be explained in more detail below.

In the following we focus mainly on interdisciplinarity, which comprises a whole spectrum of activities depending on the level of integration. The weakest form is when two or more disciplines contribute their particular disciplinary knowledge on a common subject, such as women’s studies. The strongest form is ”integration and even modification of the disciplinary subcontributions while [an] inquiry is proceeding. Different participants need to take into account the contribution of their colleagues to make their own contribution” ([3], p. 9). Disciplines combine their expertise to jointly address an area of common concern, such as AIDS, global warming and climate change, or obesity. As explained above by the example of computer science, this strong form of interdisciplinarity can establish a new discipline. Another example in that context is Environmental science, which can be regarded as a new discipline. On the other hand, the traditional discipline of Geography can be regarded as an interdisciplinary field involving physical and human studies [1]. Therefore definitions regarding (inter)disciplinarity are far from clear and as mentioned above also change with time.

### 2.2 Interdisciplinarity in undergraduate education

In academic practice, a discipline provides ”the structure of knowledge that trains and socializes members of a faculty” and offers a ”standard educational pathway for students” ([2], pp. 1,2). Irrespective of disciplinarity, modern degree courses develop ”problem-solving, high-level cognitive strategies and transferrable skills” ([2], p. 4). In general one can distinguish three kinds of degree courses [2]:

- **Professional degrees** such as medicine, engineering or architecture, which have a tight relationship with employment. Graduates go into one or a few occupations and mostly do not continue doing further research. Such courses are typically taught at universities and polytechnics.

- **Academic degrees** such as literature, geography or biology, which have strong links with research and are mainly concentrated in universities. A relatively high proportion of graduates go on to further studies, or seek employment in a wide variety of jobs.
• **General degrees** such as humanities, social studies or natural sciences, which are faculty-based rather than department-based and do not have a tight relationship with either employment or research. They are often taught at polytechnics and colleges of higher education and tend to have lower status in the eyes of academics.

Courses where several subjects are studied in parallel have existed for a long time. For example a traditional Masters degree (MA) in Germany comprises several (at least two) subjects such as (foreign) languages, and subjects from social sciences. In such a modular structure no two students might necessarily do the same modules, which are often taught for specialists in a given discipline. Therefore integration and synthesis of different disciplines is typically not achieved and most of such programmes are multidisciplinary. On the other hand, many professional courses such as Medicine, Engineering etc. involve the integration of a number of foundation or contributory disciplines. In that sense these courses often really are interdisciplinary, although the word is in general not applied here. They have a well defined identity and contributions from different disciplines are seen in a more practical way as service teaching by other departments. Examples of traditional interdisciplinary academic degrees could be Classics or Medieval studies.

In the following we would like to focus on more recent interdisciplinary programmes in the area of academic and general degrees, such as Biotechnology, Environmental studies or Cultural studies. The introduction of such courses is largely driven by the need of research capacity to attack new problems which do not fit in traditional disciplines. These developments are often faster in industry and economy where many of the calls for students with interdisciplinary skills amenate [4], operations research being a classical example. In this sense interdisciplinarity is well justified as long as it is required by the problem and adds additional value to the possibilities of inquiry. But in public opinion 'interdisciplinarity' itself is often a perceived as a positive thing. So besides genuine reasons to establish an interdisciplinary degree driven by the content of a course there are also many 'political' reasons related to funding possibilities and public appreciation, which can of course be problematic from an academic point of view.

Is anything of value learned in an interdisciplinary course beyond its disciplinary content? According to [5] the answer is yes, including the following: strong sense critical thinking, and multilogical thinking, i.e. the ability to think accurately and fair-mindedly within opposing points of view and contradictory frames of references; and further the ability to evaluate experts’ testimony, tolerance for ambiguity and sensitivity to ethical issues. However, there is an inherent lack of statistical data regarding the question on how interdisciplinarity promotes learning. Therefore there is virtually no empirical evidence to support the above claims, they are merely expert opinions based on existing theories of learning and education [6]. Furthermore, questions raised by interdisciplinary courses may be more interesting to students and thereby motivate their learning, as well as engaging students in authentic tasks. Interdisciplinary problems are often not well-structured, i.e. they do not have a single correct answer that can be found, but require the use of reflective judgment. But the effectiveness of interdisciplinary education may depend very much on the individual student, and also this effect has not been studied systematically so far.

More recently in the United States general education courses without disciplinary prerequisites are adopted by more an more colleges. An example praised in [5] is the the School of Interdisciplinary Studies at Miami University, Ohio. An argument in favour of such programmes is that interdisciplinary general education requires an informed appreciation of the perspective of other disciplines, not expertise in their full range of concepts, theories and meth-
ods. On the other hand, "there is a commonsense case for suggesting that the best education that can be provided to students is a sound discipline-based one, with opportunities for interdisciplinary discussion when it is warranted. [...] An education that is too broad might not allow for sufficient expertise in the home discipline" ([2], p. 4). The most relevant features of disciplines for education is not so much the area of study, but cognitive maps, frameworks and paradigms, i.e. the way to 'see' things, and the disciplinary language, which is important to teach methodologies, procedures and concepts [2]. "Becoming an excellent disciplinarian demands undivided focus. Expertise is the result of substantial amounts of training, and the empirical evidence suggests that this training is not transferable" ([2], p. 6). Working in quantitative science I strongly support this view and in my opinion interdisciplinarity in education should be focused at the postgraduate and research stage. This is also in accordance with [1] and with reality, where many interdisciplinary programmes are actually second degrees. Programmes such as praised in [5] can make sense in the category of general degrees, where the emphasis is on breadth rather than depth, and which (rightfully) have lower status among academics.

2.3 Interdisciplinarity in postgraduate education and research

A first rise of interdisciplinary degree courses in the UK took place in the seventies, largely driven by idealistic ideas about revolutionizing science [1]. This turned out to be harder than expected and lead to necessarily painful experiences and a decline of such courses in the eighties, which is also due to general cuts in the funding of universities. Recently, the emphasis on employment relevance in higher education led to accentuated professional forms of interdisciplinary work. Also the establishment "of high-profile interdisciplinary research centres underlined the importance of such work at the postgraduate level" ([1], p. 208).

Conducting interdisciplinary research in traditional doctoral programmes is very challenging [4]. In any case the student has to master knowledge and reconcile conflicting methodologies in several disciplines, and find an intellectual community for discussion. The practical problems that have to be faced range from finding a suitable advisor to overcoming organizational hurdles, since department based doctoral programmes are often not designed for interdisciplinary PhDs. Institutional support and systems of rewards for interdisciplinary research are needed both for students and faculty members. Therefore recently a lot of interdisciplinary DTCs have been established with EPSRC funding, examples in Warwick are Molecular Organisation and Assembly in Cells (MOAC), Systems Biology and Complexity Science.

Even if the infrastructure is right, interdisciplinary research projects are still a nontrivial and delicate issue (50% of such collaborations fail [2], p. 5). The key is to mutually agree on a common problem or idea which is worth being studied from each contributing discipline. Since there are huge differences in language and methodology, the ways to attack that problem may be very different or even incompatible to start with. So the only common ground is usually the problem itself, such as global warming where at least the idea is now mutually agreed on (even that took a while). But often interdisciplinary research runs the danger of being done not for any legitimate academic reason, but simply "for the sake of being interdisciplinary" ([2], p. 6) which was already mentioned in the context of degree programmes. This is of course to harvest additional rewards connected to interdisciplinarity in research funding, and is hard to avoid.

In accordance with the above remarks on expertise and excellence, "one tends to see good disciplinarians uninterested in interdisciplinary efforts, and many who are interested seem to have marginal disciplinary competence. [...] The rewards simply due to disciplinary compe-
entence are likely to pull an [extremely competent] individual away from the interdisciplinary effort. Likewise, the person of extremely broad interests but lesser disciplinary talent may feel the project is going well, when it, in fact, never gets beyond the superficial” ([3], p. 10/11). These remarks are now 30 years old and today there may exist more excellent interdisciplinarians. But most of them will actually be well established disciplinarians, who at an advanced stage of their career switched their attention to interdisciplinary research. Early-career researchers are often drawn away from interdisciplinarity, since colleagues may not value publications in journals outside of the home discipline, and most permanent positions are still located in traditional departments. It is true that cutting-edge work goes on in boundaries and margins of disciplines (almost by definition of the word), but basic foundational work mainly remains within individual disciplines. In this respect it is not clear how interdisciplinary PhD research is favorable for an academic career. The UK might be a very good example on the forefront of this development, but other European countries such as Germany or Italy are much more rigid in their academic structure.

3 Complexity Science at Warwick

3.1 What is Complexity Science?

First, what do we mean by Complexity Science? Well . . . this itself is a complex question, the following is an attempt compiled from a few sources on the web [7, 8, 9].

Complexity science is a broad term for understanding a range of complex phenomena. “It focuses on systems of many interdependent components, showing emergent behaviour at the system level, self-organisation, [adaptation] and/or evolution” [9]. Another characteristic feature are different scales or levels of inquiry and analysis, bridging the gap between the individual and the collective, for example, from psychology to sociology, from organism to ecosystems, from genes to protein networks, from atoms to materials, from the PC to the World Wide Web, or from citizens to society. Loosely speaking, “if you break down a [complex] system into its basic components and analyse how the components behave, you can recreate the behaviour of the whole system by running all the components together” [7].

In contrast to a common belief among many non-scientists, there is no single well defined methodology in complexity science, which comprises a very diverse collection of approaches. On the other hand, phenomena with the above features can be found in many areas of science, social sciences and arts. Therefore complexity science is clearly not a discipline since it has neither a well defined area of study nor a common methodology. Rather it ”claims or at least strives to address a very wide and increasing range of phenomena in all science” [8], using various techniques from mathematics and physics such as agent based computer models, chaos, networks, emergence and fractals and also statistical mechanics. The latter is of particular importance, a classical subdiscipline of physics that has dealt with complex systems for almost a century, more recently reaching out in many areas of quantitative science such as economics or biology. However, these studies were mostly driven by physicists alone and not so much by interaction with other disciplines, so it was mostly cross-disciplinary work as explained above.

The ambition of complexity science on the other hand is a truly interdisciplinary one, interaction with experts from other disciplines and integration of their knowledge and questions into the project. Aspiring to realize this ideal of interdisciplinarity, the Complexity Centre at Warwick has a lot of connections to end-users. But as usual this goal might be hard to achieve.
in practice since communication with disciplinary experts can turn out to be very difficult. The methods of complexity science being in mathematics, it works quite well in connection with quantitative areas of science, such as economics, chemistry or biology, the latter being particularly important. Cooperation with non-quantitative sciences such as sociology is much more complicated and often not even a common problem can be agreed on (see Section 2.3).

Because the word ‘complexity’ is of course often used in a rather loose sense also by non-scientists, there is the danger that it is perceived as a non-quantitative ‘soft’ science, and there is a large community of people using it in exactly that way. Therefore we always talk about complexity ‘science’ stressing the quantitative, scientific approach, and the Centre for Complexity Science in Warwick focuses on this meaning of the word. It “draws from some aspects in existing fields, including mathematics from dynamical systems and chaos, statistical inference, physics of phase transitions, self-assembly in chemistry, network modelling in biology and neuroscience, interacting agent modelling in economics and computer science. We also look to apply scientific methods in new fields of opportunity, such as transport, health and social science applications where mass quantitative data is newly available in this information age” [9].

### 3.2 Complexity Science Doctoral Training Centre

A central part of the Centre for Complexity Science at Warwick is the Doctoral Training Centre (DTC). Below we shortly introduce its curriculum with material largely taken from [9].

The DTC has EPSRC funding to train 4 cohorts of 8 PhD students in an integrated Masters/PhD programme. In their first year the students take on 8 modules in terms 1 and 2 that introduce them to various aspects of complexity science, which is explained below. Each module comprises theory and principles, through lectures and/or study groups working to jointly understand directed reading, as well as consolidation by application, through classwork both analytical and computational, with a large component of group work in which students are challenged to work as a team, dividing responsibility, communicating results, and sharing in the outcome. Key aspects of the classwork are problem based learning and team/group work, which is an essential part of practising research. Embedded within the classwork is a systematic development of numerical and computational technique. The first modules promote simple computational experience using accessible packages such as Matlab, leading on in later modules to developing fully compiled code and issues of numerical algorithm and stability. The modules are assessed partly by class-work and/or presentations, and 50% of the final grade is determined by an oral examination.

Students undertake two successive 12-week miniprojects in each of term 3 and the summer break, which should have some connection to the end-users associated with the centre. In each case a member of staff on campus is contributing to (or leading) the supervision. The projects generally comprise one week of prior reading, ten weeks of active research, and finally presentation of results in a formal report and a scientific conference format, this year a poster and a talk for miniproject one, and a talk only for miniproject two. After passing the MSc with at least 60% the students are eligible to proceed and will take up their PhD projects. Choices of miniproject do not bind students’ choice of PhD project, but certainly serve as a prospective taster (both individually and through group opinion). The projects are supervised by two researchers, at least one a member of academic staff (the second supervisor might be an end user off-campus). Where both supervisors are on campus they should have complementary scientific backgrounds. The projects run for 3 years and are subject to six-monthly monitoring.
by the DTC and annual presentation of progress. In addition students receive training in transferable skills within another core module in year one and a certificate during the PhD years. They are also required to take at least one further masters level option e.g. from other DTCs at Warwick (such as MOAC or Systems Biology) or the Centre for Scientific Computing.

The primary recruitment base of the DTC are practically inclined graduates in mathematics and mathematically inclined graduates across sciences such as physics, engineering and chemistry, plus quantitative social sciences such as economics and business studies. The students will receive an MSc and a PhD in 'Complexity Science’, which is believed to be an attractive title for successful employment in industry and economy. For the academic job market it is possible – and may indeed be useful, as explained at the end of section 2.3 – to augment the PhD title by a specific discipline the student specialized in, such as 'Complexity and Physics’.

The full curriculum of the core modules CO901 to CO907 can be found on the web [9] and a summary list is given in Appendix A.1. In the first half of term one students take a general introduction to basic phenomena in complex systems (CO901) and learn how to analyse data in a statistics module (CO902). The second half contains a discussion of deterministic dynamical systems that show complex behaviour such as chaos (CO903) and basic principles of statistical mechanics (CO904). Term two starts with a mathematical introduction to stochastic processes (CO905) and partial differential equations with an emphasis on numeric solutions (CO906), and ends with an applied module on spatio-temporal complexity (CO907). With the exception of CO906 and CO907 all modules this year were taught by staff with joint appointments in the DTC and the department of their home discipline which is physics, statistics, computer science or mathematics.

3.3 Results from practical experience

The DTC has now completed its first year and in this section we reflect on the teaching outcomes and other experiences. As a basis we have the students’ feedback data that have been collected for every core module [11] (an integrated version of those is summarized in the appendix), and detailed notes from an intense discussion session at the annual retreat [10].

The curriculum. Do we teach the right things?

As explained in section 3.1 complexity science is not a well defined discipline and there is no standard curriculum that could be adopted for the course. The student feedback indicates that the selection of topics in individual modules was in general interesting and useful, and we agreed that also the whole curriculum as it stands is largely fine and adequate. Topics which only occurred implicitly and should be covered more systematically are most importantly (random) networks, and maybe also self-organized criticality, agent-based modeling and information theory. Also, not surprisingly for the first year of a degree programme, some inconsistencies have been identified: Most importantly some knowledge expected on spectral analysis of time series has not been provided and will be part of CO905 next year.

Although there have been little complaints about that: In order not to overload the curriculum, this also implies a careful check of which parts actually really essential. The lectures of core modules should really comprise core material, and more exotic/optional parts should be left to the classes. This will also make it easier to emphasize the connections with previous modules, which is very important for synthesis and integration of the material. This is an essential part of an interdisciplinary course and requires special initiative by the lecturers, since the modules do not a priori build on each other like in a traditional degree course.
Method of teaching/assessment.
As explained in section 3.2 the methods used for teaching are quite diverse and adequate for a modern degree course. In general the students’ feedback was very positive about this. In particular critical thinking exercises and group work was very popular, but the latter was not adopted to the extend that was anticipated and should be increased as much as possible. The flavour of each module is determined by the background of the supervisor. Quite naturally staff tended to largely stick to the cognitive maps and language of their home discipline, none of them being a complexity scientist by training (if such a person even exists). This creates the rather challenging task for the students to master or at least get acquainted to mindset and methods from different disciplines. But on the other hand, this is one of the major learning outcomes of the programme and will enable them to communicate with researchers from various disciplines and get to know different disciplinary cultures. Since the staff is also dedicated to interdisciplinarity, they provided alternative ways of explanation whereever necessary, and in general this point was not perceived as problematic by the students.

After initial scepticism vivas were very popular with the students, most of them never had a viva during their undergraduate degree. Also the other forms of assessment such as class work or presentations were well received.

Student background. “What matters in the end is the phenomenology of the student’s experience rather than the formal intentions of the lecturers” ([1], p. 209).

What the students take home from a module also depends very heavily on their own background. Whenever you learn something new you try to relate this information to existing structures in your memory. This form of learning is called ‘accretion’ (as opposed to ‘restructuring’ [1]), and the stronger the relation to previous knowledge, the easier it is to remember and understand. This was very clearly represented in the students’ feedback, for example students with physics background could make more sense of CO904 than others, whereas students with maths background could relate easier to CO905 than others. In general, due to the mathematical orientation of the programme, students with a mathematics (or physics) background had less difficulties than other students. On the other hand, the students’ judgment of their own background reveals that there was a substantial amount of new material in all the modules. It is also clear that not all material from all the disciplines contributing to complexity science can be taught within a single year so that each student has the same learning experience.

The diverse student background is one of the most challenging and important aspects of teaching in the DTC or interdisciplinary courses in general. It deserves special ‘interdisciplinary’ attention in the sense of integrating and engaging with the students’ prior knowledge. The teachers all have a home discipline and the way they make sense of what they say may be completely different from the way the students understand it. This is also confirmed by the fact that one module that was shared with several other traditional degree programmes did not go down as well with the students as other modules taught specifically for the DTC, leading to a bimodal distribution of the students’ feedback on the accessibility of lectures. This problem is largely absent in traditional department teaching and can therefore be easily underestimated.

In general the maths background of most of the students was appropriate. However, two areas have been identified which were not mastered sufficiently by everybody, linear algebra and (linear) ordinary differential equations. A basic knowledge here is essential since a lot of methods in complexity science build on these areas. They are not part of the curriculum, but given their importance maybe a few revision classes could be offered in term one.
4 Conclusion

At present there is no data and no clear answer from educational theories whether interdisciplinarity itself promotes learning. Rather this can be the case due to secondary effects, such as enhanced students’ interest and innovative teaching methods. Those may be more likely to be adopted in interdisciplinary courses mainly because such programmes are new, but are by no means restricted to them and could be used in disciplinary courses as well. There are conflicting opinions but many of the experts agree that interdisciplinary courses are better suited for the graduate and research level, where they are very important. On the undergraduate level a decent amount of training in foundations is required, which is often specific to a discipline. In the author’s opinion for example an undergraduate degree in complexity science could be at best a general course at a merely qualitative level, since a quantitative approach requires a certain background in mathematics.

Also on the graduate level interdisciplinary courses involve special challenges and difficulties, which have been illustrated in some detail for the Complexity Science DTC at Warwick. We conclude with a summary of the main issues that have been identified.

Points that have been largely agreed upon by staff and students:

- cover the following topics more systematically, in ascending order of importance: (random) networks, self-organized criticality, agent-based modeling, information theory
- cover spectral analysis of time series before module CO907
- connect as much as possible to other modules in the DTC, in particular if your module is shared with other degree courses use the classes to do that
- stick to language and methodology from your discipline, but keep in mind that both can be new to the students
- secure a decent background in linear algebra and linear ODEs

For most of these points specific actions have been decided. Open issues with the curriculum that have not been considered so far, but I think might be worth discussing:

- include only real core material in core modules and in the long run try to concentrate the core material (once well defined) in fewer modules
- This could increase the number of optional modules of which there is only one at present. In my view the choice of these modules is also very limited, there are only three as listed, all in the area of biology/chemistry. Although in practice students could choose to follow another course of their choice in agreement with the programme coordinator, to my knowledge this happened only in one case last year.

5 Acknowledgments

I would like to thank my colleagues and the students from the Complexity Science DTC for very interesting discussions that inspired this project, and in particular Jamie Luo who provided me with the material in [11].
Appendix

A.1 Summary of the DTC curriculum

The following material is taken from [9], where more details can be found.

- **CO901.** Self-organisation and Emergence. Introduction to systems of many agents and networks with simple rules but more complex organised behaviour.

- **CO902.** Complexity Science in the real world. This will extend the scope of module 1 and introduce students to acquiring and mining data from diverse methodologies, secondary analysis and the challenge of imperfect and subjective data.

- **CO903.** Complexity and Chaos in Dynamical Systems. The module aims to introduce some of the techniques used in the modern theory of dynamical systems and the concepts of chaos and strange attractors, and to illustrate a range of applications to problems in the physical, biological and engineering sciences.

- **CO904.** Statistical Mechanics and its Applications to Complex Systems. This module aims to survey the tools of Statistical Mechanics and show examples of their use outside the traditional application domain.

- **CO905.** Stochastic Processes. This module covers the description and analysis of systems with stochastic time evolution, including interacting particle systems, and applies information theory concepts.

- **CO906.** Partial Differential Equations and their Computation. Partial differential equations are the natural mathematical framework for complex systems which extend in space and time (given some local smoothness). This module will address methods for numerically solving the most important types of partial differential equations which arise in practice. Teaching is shared with Engineering module ES440.

- **CO907.** Quantifying correlation and spatio-temporal complexity. This module introduces students to methods for analysing complexity in extended systems, including the real world challenges such as incomplete data, extrinsic noise and non-uniform sampling.

One optional module to choose from: CH926 Molecular Modelling, CH927 Metabolic Pathways and Regulatory Networks, BS917 Modelling and statistics in Systems Biology.

A.2 Student feedback

The following are integrated data from all student feedback forms for the modules CO903 to CO907. No such data have been collected for CO901 and CO902, but the minutes of the relevant SSSL meeting [11] demonstrate that these modules fit in the general pattern.

**Scale:**
5: strongly agree, 4: moderately agree, 3: neutral, 2: moderately disagree, 1: strongly disagree

- I started the module with a strong background in the subject.
  5: 1  4: 10  3: 4  2: 8  1: 14  total: 37  \( \text{av: 2.35} \)

- The assigned work could be completed in a reasonable amount of time.
  5: 3  4: 17  3: 11  2: 3  1: 0  total: 34  \( \text{av: 3.59} \)
• The lectures were clear and accessible.
  5: 9  4: 8  3: 5  2: 7  1: 8 total: 37  av: 3.08
• Topics covered were relevant to my educational goals.
  5: 16  4: 12  3: 4  2: 1  1: 3 total: 36  av: 4.03
• The viva effectively evaluated my understanding of the material.
  5: 8  4: 10  3: 12  2: 2  1: 2 total: 34  av: 3.59
• The classes effectively supplemented the course material.
  5: 2  4: 4  3: 6  2: 4  1: 7 total: 23  av: 2.57

Average hours per week outside of classes spent on each module: 5.97

References


[7] EPSRC website on the meaning of Complexity Science http://www.epsrc.ac.uk/ResearchFunding/Programmes/CDI/ComplexityScience/WhatWeMean.htm


[10] personal notes taken by S. Grosskinsky during the Complexity Science DTC annual retreat at the Stanton Guildhouse, June 2008

[11] student feedback forms for the Complexity Science DTC core modules; minutes by Jamie Luo of SSLC meetings from 14.11.07, 16.01.08 and 20.02.08