"Mastering another language" – a case study in interdisciplinary teaching and learning on food security across two countries and two universities

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Abstract

Household food security is a complex societal problem requiring a multifaceted approach to evidence-based policy design. We present a case-study of interdisciplinary pedagogy derived from a collaboration between mathematical sciences and public health nutrition to deliver content on food security based on those two disciplines together with complex systems science and social sciences. This content was designed as a five-lecture series and delivered for students in two universities, one in the UK and one in Australia, with different backgrounds and within different courses where consideration of food security was part of each. Student evaluations were gathered via a Qualtrics survey and module convener feedback was sought for the five-lecture series within the broader modules. We provide an overview of the content and context of the design and delivery, and the views of module conveners and of students as evidenced by the survey. We discuss the experience of designing interdisciplinary teaching and learning in the light of interdisciplinary pedagogy theory, with a particular focus on language.

Peer review: This article has been subject to a double blind peer review process

Keywords:

Interdisciplinary pedagogy; food security; interdisciplinary language; pedagogical design; interdisciplinary labour; interdisciplinary academic career

INTRODUCTION

As researchers tackle increasingly complex societal, industrial and other problems, more and more are turning to interdisciplinary working to provide the necessary breadth of insights. For research-led teaching in Higher Education, this inevitably means introducing interdisciplinary teaching and, in some cases, for mixed-discipline audiences. Interdisciplinary courses are increasingly offered at many Universities, although the idea is sometimes contentious (The Guardian, 2018).

Problem complexity is one of the main drivers of multi-, inter-, and transdisciplinary approaches to knowledge production and application (Darbellay, 2019). Overarching thematic areas, such as sustainability or big data (Klaassen, 2018) or complex societal issues (Giabbanelli et al., 2012; Spelt et al., 2009; Woods, 2007) such as food security often require different disciplines to create joint solutions.

Food security a complex public health and societal issue in high income countries. Food security is broadly defined as when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets the dietary needs and food preferences for an active and healthy life. Food insecurity exists whenever the availability of nutritionally adequate and safe foods, or the ability to acquire acceptable food in socially acceptable ways, is limited or uncertain (Food and Agricultural Organization of the United Nations Committee on World Food Security, 2012).

In this paper we first discuss interdisciplinarity in general and then how it links to pedagogical design. We then outline the lecture series we developed, introducing the context of food security and content of the lectures. Next, we share the student and staff responses to the course delivered in UK and Australian institutions. We end with some reflections on our experience and links of our design to interdisciplinary pedagogy theory.

DESIGN FOR INTERDISCIPLINARITY

Disciplines and interdisciplinary

Academic disciplines came about in 18th century (Weingart, 2010), and led scholars from being polymaths to specialists, changing their audience from 'public' to scholars within disciplines. This public is not the public as we might think in our days of mass media, but rather a limited public of the educated and otherwise privileged. Disciplines emerged as knowledge grew to the point where it was no longer possible for one person to acquire all knowledge (Weingart, 2010, p.4). Each discipline developed its own signature pedagogy (Schulman, 2005), language, and notions of excellence. Interdisciplinary working entails the acquisition of multiple language conventions, context-specific meanings, ways of working and notions of excellence, some of which may conflict with conventions in a home discipline. It is considered as a complex cognitive skill (Spelt et al., 2009).

There are a number of descriptions of interdisciplinarity, some focussing on methodology and problems, and some are more people-focussed. Frodeman emphasises the audience, asserting that disciplinary knowledge production is principally defined by the audience of a limited group of peers who will audit and approve the work (Frodeman, 2014, p.35). Interdisciplinarity, the blending or integrating of different types of disciplinary knowledge, focuses outwards. In multidisciplinarity, which juxtaposes different bodies of knowledge without blending them, each part refers to its own audience. Newell describes interdisciplinarity study as a process of answering a question, solving a problem, or addressing a topic that is too broad, or complex to be dealt with adequately by a single discipline or profession (Frodeman, 2014, p.43). Klein describes Interdisciplinary studies as a subset of integrative learning that fosters connections among disciplines and interdisciplinary fields (Klein, 2005). Spelt *et al*. define interdisciplinary thinking as the capacity to integrate knowledge of two or more disciplines to produce a cognitive advancement in ways that would have been impossible or unlikely through single disciplinary means (Spelt *et al.*, 2009). Transdisciplinary is co-production based on joint ownership, responsibility and commitment of researchers and practitioners.

Frodeman claims that interdisciplinarians have implicitly imported disciplinary standards and perspectives into their efforts (Frodeman, 2014, p.6). There is broad agreement that socialisation into a discipline subtly shapes ways of thinking and orientations to learning and this can ultimately lead to mutual incomprehension when specialists from different subject domains try to collaborate (Woods, 2007).

> *Once ingrained in a certain discipline it will be hard to lower the disciplinary egocentrism* (Klaassen, 2018 p852).

It is inevitable, therefore, that disciplinary perspectives come into interdisciplinary teaching and research. This may present a barrier to be overcome. In order to work in an interdisciplinary way, researchers need to reflect and recognise that they have been shaped in their thinking, approach and conceptions of excellence by the signature pedagogy of the discipline in which they were trained. Disciplines can differ markedly in terms of teaching methods, knowledge claims, curriculum content and organisational cultures (Pharo et al., 2014). Discomfort experienced in interdisciplinary endeavours derives from moving from the familiar in to the unfamiliar and becoming beginners again – the kind of humility Frodeman says is essential:

> *But all thinking, and especially interdisciplinary thinking, should begin in receptivity and rhetorical nuance rather than with methodological prescriptions. Skill at interdisciplinary work thus becomes a matter of character rather than methodology* (Frodeman, 2014, p.48).

A precondition for operating in the interdisciplinary arena is to be open to other disciplines, perspectives and people and knowing the process of going from being a disciplinary outsider to becoming a disciplinary insider (Klaassen, 2018). This is not always a comfortable experience (Wright *et al.*, 2008). For some, moving away from their comfort zone may be difficult (Giabbanelli *et al.*, 2012). Part of the labour is to learn enough of other disciplines for linguistic 'code switching' to be able to be understood in the host discipline. An accent can be thought of as somebody speaking your language with the rules of theirs. Similarly, the approach of interdisciplinary scholars can seem stilted to disciplinary audiences. Another challenge is that modes of evidence and the expectations with regard to argumentation vary between disciplines, contribution to differing notions of rigour. This has profound implications for research, teaching and assessment. But perhaps it is also an opportunity for more authentic assessment of intellectual accomplishments that are worthwhile, significant, and meaningful.

Interdisciplinary research has led to the creation of sub-disciplines (e.g. medical statistics) and hybrids (e.g. mathematical Biology). In some cases, funding has 'recognised' them, especially at postgraduate level through interdisciplinary and centres for doctoral training, which provides visibility and facilitates working. The question then arises when do such endeavours become new disciplines? Klaassen (2018) suggests a topic will become a new mono-discipline when it has realised a full integration of contributing domains and is able to build a new disciplinary domain with its own register, cases, disciplinary questions, methods, outcomes and profession.

> *In higher education, we see the merger of different existing disciplines to become a new specialism drawing on both, moving from mono- to multi- to inter- and back to monodisciplinary studies with their own newly formed foundational theory, methods and approaches* (Klaassen, 2018 p856).

The point of departure for the design of education are the research questions that need to be asked or reframed and the questions that go beyond the disciplines as we know them (Klaassen, 2018). It is asserted that such programmes, which may inform policy, help attract the brightest students and increase overall enrolment (Giabbanelli et al., 2012). Building trust, tolerance and mutual respect is essential in interdisciplinary collaborations as is the ability of team members to robustly deliberate points of difference, to air confusions, uncertainties and convictions (Pharo *et al.*, 2014), between academics, researchers, problem owners (Giabbanelli *et al.*, 2012), and professionals in interprofessional settings (Wright *et al.*, 2008).

The focus on audience, emphasised by Frodeman, can be a useful way of thinking about interdisciplinary teaching, where the student audience may be from single or mixed disciplines. In these contexts, educators will need to consider how much of their disciplinary signature pedagogy can be assumed or used, and how students can be expected to acquire new ways of thinking and working. Additionally, the assumption that students may be able to integrate information from different disciplines independently may be fallacious (Klaassen, 2018). Students with formal training in interdisciplinary learning are better able to handle sometimes emergent, contradictory, ambiguous and context-dependent learning experiences (Pharo *et al.*, 2014). Specific support and learning tasks intended to develop interdisciplinary thinking appear to be important. Students' problems in working across disciplines, working in different disciplines and synthesizing different disciplines may be caused by disciplinary differences in epistemologies, discourses, and ways of teaching (Spelt *et al.*, 2009). Related to this, educators need to have some idea about a common language, rather than simply assuming that disciplinary language or technical expressions will effectively communicate concepts; communication is pivotal to any learning encounter (Woods, 2007).

Language

As disciplines formed, specialist language, signature pedagogies and notation conventions developed to speed up communications within disciplines but added a layer of separation, which can give rise to difficulties in communicating between disciplines. In the UK context, students perceive mathematics as a difficult subject that exposes the weakness of their intelligence and reduces their confidence in their intellectual capacity (Nardi and Steward, 2003). Such attitudes can persist into higher education, especially if they have a fixed mindset (Dweck, 2006).

> *Mathematics uses everyday words, but their meaning is defined precisely in relation to other mathematical terms and not by their everyday meaning. Even the syntax of mathematical argument is different from the syntax of everyday language and is again quite precisely defined. The issue that frequently arises is how this abstract, separated mathematics can be made useful for the real world and relevant to the learner* (White and Mitchelmore, 2010).

Fields medallist and Breakthrough Prize in Mathematics winner Prof Martin Hairer said,

> *We could turn every equation into a piece of text, it's just that the one line equation might be half a page of text or more, so it is easier to visually take in one line than half a page, therefore it is much more efficient to communicate using these equations.* Martin Hairer. Interview with Martine Barons & Paul Chleboun (Barons and Chleboun, 2015 P22).

Signature pedagogy in mathematics developed through international, predominantly male groups. Pure maths derived from astrophysics and engineering. So pure and applied mathematics connects easily to physics, statistics, computer science, engineering, operational research and business. Matching the language of contributing disciplines is a continuous point of attention until the development of new words and definitions giving meaning beyond the mono-disciplines (Klaassen, 2018).

Interdisciplinary communicative competence

Woods (2007) proposes a framework for conceptualising interdisciplinary communication, drawing principally on two theoretical models: the taxonomy of the disciplines proposed by Becher and Trowler and Byram's model of Intercultural Communicative Competence. Becher and Trowler's model provides a means of conceptualising both the socio-cultural aspects of the disciplines (the 'tribes') and their knowledge domains (or 'territories'), defining academic cultures as 'sets of taken for granted values, attitudes and ways of behaving, which are articulated through and reinforced by recurrent practices' (Becher & Trowler, 2001, p. 23) within academic communities. By giving due prominence to gaps in knowledge about language that might hamper communication between the members of different linguistic groups, Byram's model provides a way of conceiving of barriers to effective communication that will arise due to gaps in disciplinary knowledge. Woods goes on to propose a model of interdisciplinary communicative competence which comprises eight components: conceptual competence, competence in negotiating meaning, competence in interdisciplinary text production, knowledge of the products and practices of both disciplines, skills of interpreting and relating, skills of discovery and interaction in new disciplines, attitudes of curiosity and openness and finally critical disciplinary awareness in both disciplines. This model implies that, in interdisciplinary pedagogy, there is a need to provide

- preparation for interdisciplinary collaboration
  (e.g. to teach terminology, research and other practices),
- experience of interdisciplinary collaboration
- reflection on interdisciplinary collaboration.

This model also entails implications for structuring assessment of interdisciplinary learning, perhaps in requiring elements of all-group participation where all students are given a common mark and reflection element s marked individually (Woods, 2007).

Interdisciplinary design

There has been some research on how to design interdisciplinary teaching and learning.

Repko and Welch (2007) devised a nine-step plan for educators to use when designing interdisciplinary learning. The nine steps are

- Define the warrant for interdisciplinary education
- Present the rationale for interdisciplinary education
- Identify relevant disciplines
- Conduct literary review
- Develop which values or assumptions are being made in each field
- Study: relate to the problem definition
- Differences / similarities
- Create a framework for interdisciplinary learning
- Combine integrate the frame

The hypothesis using the Repko approach is that if the elements of the inductive model are used, a strong integration of different disciplines has taken place and interdisciplinarity in the educational programme is realised.

Spelt *et al.* drew a list of conditions and potential subskills for interdisciplinary higher education from a systematic review. This identified that both knowledge and skills are key to interdisciplinary thinking, including communications skills. Student characteristics including respect, openness and self-regulation are important. A good leaning environment (curriculum, teacher, pedagogy and assessment), and a learning process with patterns of phased gradual advancement, linear progression, iteration and milestones with encountering questions, learning activities aimed at achieving interdisciplinarity and reflection are also common themes (Spelt *et al.*, 2009).

Benefits and Costs of interdisciplinarity

Whilst interdisciplinary learning and research had some obvious benefits in terms of applicability to complex problems, interdisciplinary research can carry particular hazards at postgraduate level. The university is organised, and rewards hyper-specialisation (Brabazon, 2019). Interdisciplinary research can be difficult to publish, frequently 'falling between two stools' in the journal landscape. Klein and Falk-Krzesinski state that promotions was the top of five major impediments to interdisciplinary research in a 2004 report, as academics are judged primarily by their discipline-based standards and their contributions may be under-valued if they are not first author on publications or PI on a grant (Klein and Falk-Krzesinski, 2017). They concluded there needs to be more favourable campus cultures for interdisciplinary work to recognise the significance and prevalence of interdisciplinary work in advancing science. In the UK, the Impact, knowledge exchange and industrial strategy agendas may have helped universities to develop more supple institutional structures (Pharo *et al.*, 2014) capable of adapting to reward translational work and knowledge exchange activities, but may not always recognise the slower production rate due to time required for gaining new knowledge and language and social and intellectual cohesion in a multidisciplinary team. Recognising interdisciplinary teaching can be achieved by adopting a portfolio approach for hiring and promotions, moving beyond standard proxy measures of publications and grants (Klein and Falk-Krzesinski, 2017).

The cost of interdisciplinary working can be exacerbated by administrative marginalisation through workload allocation and budget disincentives (Pharo *et al.*, 2014). Departmental workload models that do not recognise staff teaching in other departments and disincentivise interdisciplinary participation. This impacts student projects, dissertations and postgraduate research supervision; there may be structurally derived limits to the topics that are available to them, even within a deliberately interdisciplinary course. In practice, it is often the working relationships between colleagues that are the key to success or failure of these arrangements. In some cases, a facilitator plays a key role in facilitating and mediating cross-disciplinary negotiations within the community, sustaining it and enabling educators to remain involved (Pharo *et al.*, 2014).

Assessment for interdisciplinary learning

One role of the University is to tell the students, employers, other universities etc. the level of academic standard that has been achieved, i.e. certification. Where entry is by portfolio (e.g. design, coding) this may be of less importance, but currently there is little appetite by employers to take on the detailed assessment of potential employees, for example if their education is by MOOCs. Discussion around what an employer or postgraduate course would expect a graduate of this course or University to be able to do is used as an argument for maintaining high standards and embracing the possibility that a poorly performing candidate can fail their course or examination.

Assessment of student interdisciplinary outcomes holds greater challenges since standardisation rarely exists (Madison and Augsburg, 2012). Methodological multilingualism is valuable in the workplace, and may be part of the success of interdisciplinary programmes, but may not be specifically assessed or recognised within the degree itself. The challenges include lack of consensus on what and how to assess, difficulties in assessing process rather than content, lack of confidence in ability to assess, perceived or actual increase in faculty workload and lack of familiarity with the literature on workload (Madison and Augsburg, 2012). One proposal (Madison and Augsburg, 2012) is to use institutional-level rubrics (such as the VALUE rubrics), since these can be adapted for local needs and are flexible enough to be applicable in a wider range of courses. Another approach is to create a graduate certificate in recognition of skills developed in an interdisciplinary programme (Giabbanelli *et al.*, 2012). A further approach is to involve the students in the design of the assessment so that the content and modes of assessment are the responsibility of the students (Staffordshire University, 2019). The students are free to develop and to showcase the skills and knowledge they most value and feel are most relevant in the future study and employment they wish to pursue. The University role then becomes guidance on standards and evidence that are acceptable, the delivery of the agreed assessment and certification.

THE CASE STUDY: FOOD SECURITY IN HIGH-INCOME COUNTRIES SERIES

Food Security

Food security, the reliable and regular physical, social and economic access to enough nutritious food to meet the dietary needs on a daily basis in socially acceptable means, is described as a complex public health issue in high-income countries, which requires the integration of social, cultural, economic and political perspectives. Food security can manifest at country, region, household and individual levels and phenomena that appear at different scales and the links between them is a key interest of complex systems science. In low-income countries, food insecurity can affect many households in the country; but in high-income countries, significant numbers of households can still experience food insecurity despite country-level food security. Food insecurity has implications for physical, social and emotional health and wellbeing of both adults and children.

Food insecurity arises from multiple causes that are context dependent but are predominantly situated in inadequate financial resources (Barons and Kleve, 2021), and these may vary between and within countries. The dominant response in both UK and Australia (and other high-income countries, such as USA, Canada) has been charitable food relief which supports households in the immediate crisis of lacking food, but fails to address the underlying causes.

Content design and implementation consideration

We developed and delivered a five-lecture series of interdisciplinary lectures on the problem of household food security. The teaching and learning took place in Monash University, Australia and in University of Warwick, UK, for students undertaking different courses in different disciplines, where food security was an element of curriculum in each.

During a month-long visit at Monash University, Melbourne Australia, supported by Monash Warwick Alliance Education Fund, the authors and an additional Monash academic designed a five-part lecture series on Food Security in High-income Countries, integrating three distinct perspectives. Kleve (Monash) is a public health nutritionist and researcher, the additional contributing Monash academic (McCartan) is public health nutritionist and researcher with expertise in in systems thinking and Barons (Warwick) is a mathematician, making a multidisciplinary team.

The sessions were developed for students in the Public Health Nutrition Units modules in Monash's Bachelor of Nutrition Science and Masters of Dietetics and for Warwick students on 'Challenges of global food security', a core module in both Masters in Food Security and Masters in Environmental Bioscience. The Monash students have a biomedical science, science and/or nutrition science background, The Warwick students have a wider diversity of science backgrounds from biological sciences, including crop science, and biomedical science; very few have a significant maths background. At Monash there are a mix of domestic and overseas students, the latter predominantly from Asia (China, Hong Kong, Singapore and Malaysia). The picture is similar at Warwick, with a mixture of home and overseas students, but less predominantly Asian.

Each academic had previously delivered food security related material on these modules before so drew on this experience of the kind of backgrounds the students were likely to have in thinking about food security teaching and learning. We placed the more familiar material at the beginning of the series to boost confidence and refresh prior learning before moving on to richer and more nuanced detail and newer concepts.

Each of us developed one or two lectures for the series, and recorded them against a green screen. PowerPoint slides were designed with the right third of the slide left blank and the video of the speaker was superimposed onto the slides in post-processing to form the final videos. Since we are not expert in each other's disciplines, we also created educators' notes to support in the facilitated discussions that follow the video lecture.

This material was assessed via formats that were relevant to the Units and courses at each University. At Monash this included group assignment food systems mapping, case study, and examinations and at Warwick, choices of project topic, which could, optionally, include food security.

One key motivation is granting the students access to expertise that they do not have at their home institution. Monash, Dept of Nutrition, Dietetics and Food undertakes research in household food security determinants, experiences and responses. Warwick no longer has social science research in food security, but within mathematical sciences, and particularly Statistics, has research in Bayesian decision support for food security. Bayesian modelling for food security is not available at Monash, so in that way we aimed to give students at both institutions a richer learning experience than they could have had otherwise.

Design

The basic design of each session was the presentation of the video recorded by the relevant expert followed by related group activities to consolidate, apply and reflect on the knowledge presented, designed by that academic. Material was also included for further study and could be used as pre-reading or as a basis for post-class work.

Introducing the mathematical modelling (Barons) to student with little mathematical background was assisted by the use of probabilistic graphical models, where the mathematics can be expressed in graphical form. Bayesian Networks (BNs) are a probabilistic graphical model quantified by data and expert judgement (Barons and Kleve, 2021). BNs transcend the mono-trans paradigm: the mathematics 'engine' that drives the modelling is disciplinary; the expert panels who provide their judgements to quantify the models are multi-disciplinary; the qualitative structure of the models is interdisciplinary – informed by and, ideally, finding consensus across scholars and other experts from multiple domains; the derivation of the decision-makers' utility (measure of success) is co-production and so transdisciplinary. The students can be taught to interrogate the pictorial representation of a graphical model and produce equivalent conditional probability statements which they can assess as true or not (or what they intended to convey or not). Depending on the background of the students, the idea that there are objects, which have precise definitions, and that there is no leeway for negotiation in the meaning of the model is a new challenge. Figure 1 is a simplified Bayesian Network representation of household food security.

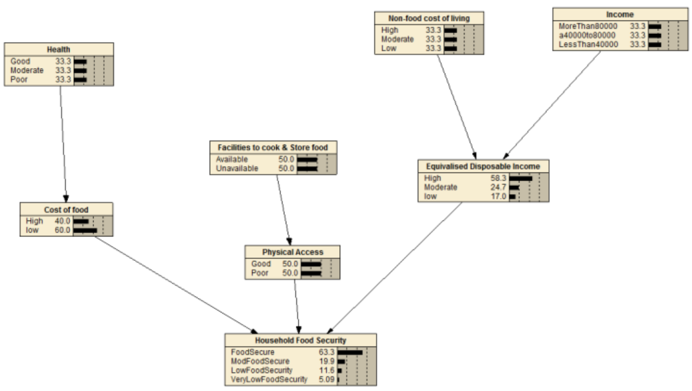

Figure 1: Simple Bayesian Network representation of household food security. Bayesian networks are used in Barons' work on providing policymakers with decision support. Data and expert judgement are used to calculate conditional probabilities and derive a score for each candidate policy under

consideration. Decision-makers define a 'measure of success', called a Utility, in order to compare the likely success of different policy decisions. Graphical representation of mathematics can circumvent the notions that what is being used is really mathematics and bypass prejudices against mathematics.

Rosenshine's principles of instruction (Rosenshine, 2012) emphasise the importance of review and success to effective learning, the introduction of new material in small steps and scaffolding, similar to Spelt *et al.*'s (2009) emphasis on iteration, phased advancement and milestone approach for interdisciplinary teaching. The repetition in our design is particularly important where disciplinary language may impose strict definitions on familiar words. Each of our five lectures builds on and expands on information and language in the previous sessions, often abstracting knowledge and using it later in a new context. For example, thinking of determinants of food security in Lecture One feeds into the language and system of causality in Lecture Five, from which the Bayesian Network representation can be built.

After the conclusion of the teaching series, Monash and Warwick students were asked to complete an anonymised, common survey. We also asked for feedback from the module conveners where our material was used. At Warwick, time was given for this during the last session, whilst at Monash students were asked to complete it in their own time after the series.

Content

The five lectures covered:

1. The concept of household food security, its causes and consequences, how it is measured and approaches to address it (Kleve).
2. Australia as a particular example of household food insecurity in a high-income country. It covers the prevalence, causes and consequences of food insecurity and explores evidence-based approaches for addressing it internationally (Kleve).
3. Food security as a complex problem, with the aim of applying systems-thinking tools and techniques to understanding and addressing food insecurity. 'System' is one example of a word which can be applied to a variety of scenarios in everyday speech, but in the context of systems thinking has a precise definition (McCartan).
4. Session four addresses complexity science in food insecurity and forms the introduction of the quantitative modelling, discussing the scales at which food security can be considered and how these scales are connected (Barons).

5. The final session addresses the role of a multi-disciplinary team in tackling the complex problem of food insecurity and introduces the formation of a Bayesian Network for decision support, the data required to quantify the model and its precise semantics (Barons). This session was the furthest departure from the background of most students.

Implementation

Monash students were final year undergraduates or Masters students. The first three lectures from this series were each delivered by Kleve in a single, two-hour (face to face session each week with an additional one hour pre and post class related activity in a flipped lecture format: Students were asked to watch the video and complete about an hour of knowledge acquisition before the lecture session where the implications and understanding of the material was explored in more depth. In particular, the elements of new language can be reinforced and clarified as required. This is supplemented with post class activity that consolidates learning.

The Warwick students were all postgraduates and all five lectures in this series were delivered by Barons as two all-day teaching seminars, lectures one to three in the first seminar and a recap then lectures four and five in the second, with a gap of several weeks between. Pre reading for Warwick postgraduates was a range of academic publications and policy reports. The videos were played in class, to change pace and delivery style during the long days.

FEEDBACK: STUDENT AND ACADEMIC STAFF PERSPECTIVES

Students

Students were asked to complete a short, anonymous online survey on Qualtrics (Monash survey platform) to gather the student feedback on the session content and implementation. The responses are five (out of 80) from Monash & 12 (out of 15) from Warwick. This is a very small sample size, so no inferences can be made about statistical significance. The survey questions are in the appendix.

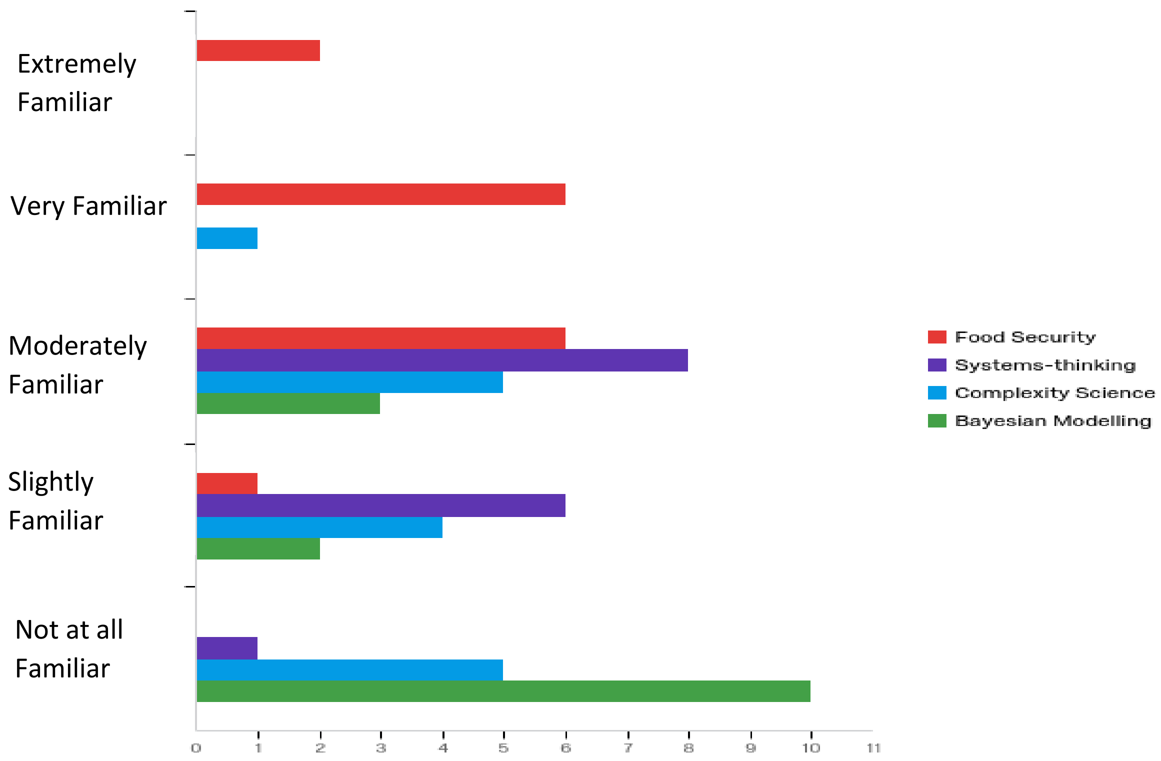

Figure 2: Student survey results: prior familiarity

All Warwick students and two of the five Monash students who completed the survey were postgraduates.

Students were asked about their prior familiarity with the four key elements of this teaching series, namely food security, systems thinking, complexity science, and Bayesian modelling (see Figure 1; numbers in Table 1, appendix).

The majority of students were familiar with some of the food security context. At Warwick, most of lecture one of this series was familiar to them, but the series quickly moved on to less familiar territory within the first teaching seminar. The majority of students across both centres were moderately or slightly familiar with systems thinking. Only one person was very familiar with Complexity Science, with the majority across both universities selecting moderately, slightly or not familiar with

Complexity Science. Most had no background in Bayesian modelling. This reflects our experience and expectations before designing the series.

We asked whether the learning objectives were clear and addressed and about the time spent on the topic, (see Figure 3; numbers in Table 2, appendix). Most students answered positively with respect to the clarity of the learning objectives, video, facilitator effectiveness and applicability of content. The majority verdict was neither agree nor disagree for time spent, with the remaining students selecting agree or somewhat agree. One respondent gave 'neither' as the answer to every question. Again, we have small numbers so we must exercise caution.

Three Warwick students made comments in the free text box:

- *Very interesting and enlightening*
- *Could have watched videos at home in preparation for the class, maybe have company/governmental examples of what is happening right now*
- *It was quite an introduction to modelling with minimal context given so I found it hard to understand what it was actually all about*

Whilst these were fairly generic teaching evaluation questions, they gave some insight into the student experience and their perspectives on our design of interdisciplinary teaching for a multidisciplinary audience. The last comment reflects the fact that most students had no background in Bayesian modelling, so it was a stretch for them.

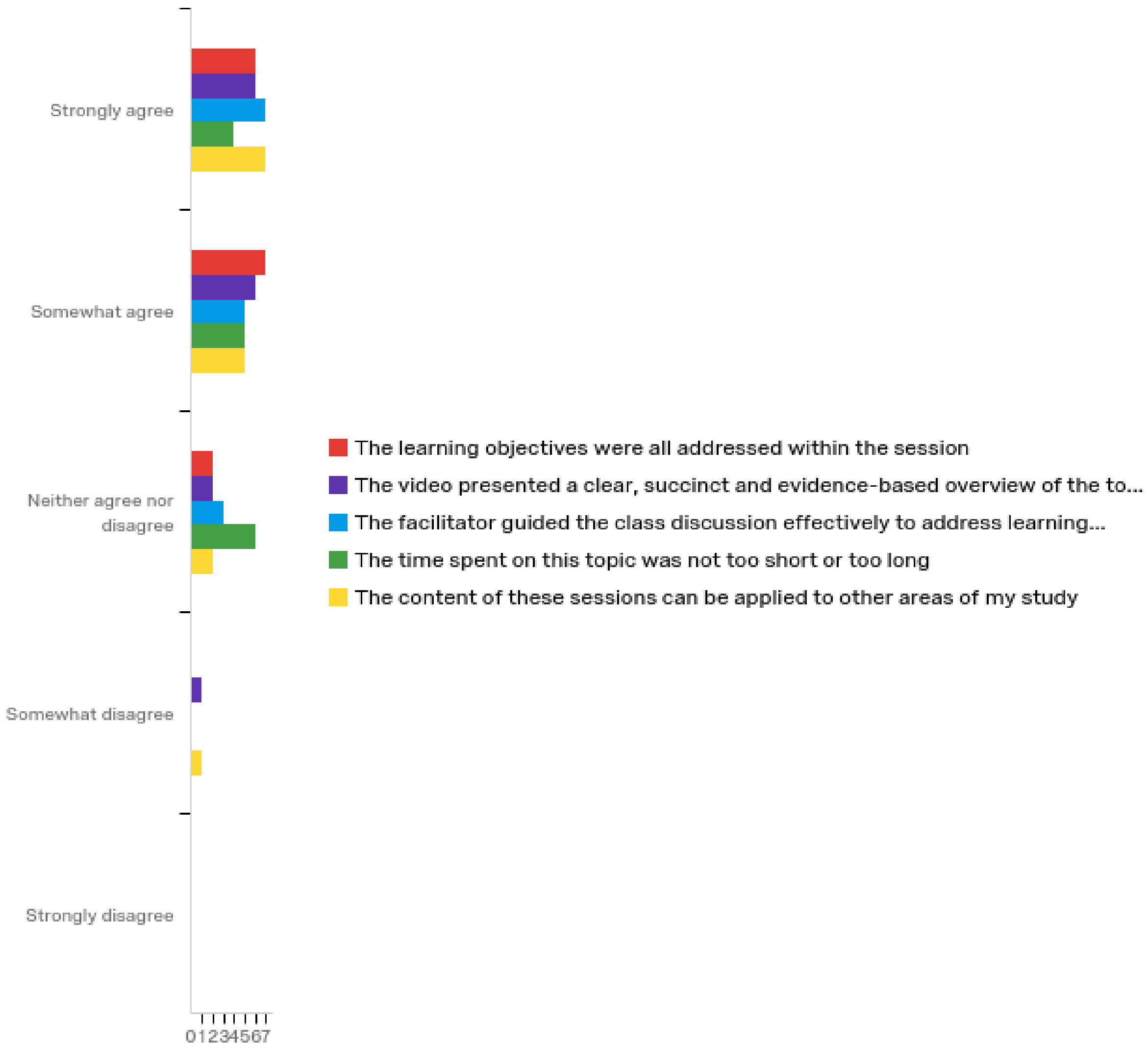

Figure 3: Student survey results: learning outcomes

We also asked independently for reflections from the module conveners. They were also positive about the lecture series.

Module conveners

Module convener's comments: Monash

- The videos allowed for the students to watch prior to the lecture time - so that they came to the lecture prepared with key background information and concepts that meant the lecture could be facilitated in much more of an applied context.

Module convener's comments: Warwick

- I think that the video series definitely improved the MSc course this year because: It got them thinking about household food security and also food security in so-called 'affluent' countries.

- This has made an impression on at least some of them.
- It got them thinking more about food systems and complexity – very valuable.
- The activities were great. The group as a whole seem to be much better at 'activities' than previous cohorts and your sessions (MJB) definitely contributed to that.

REFLECTIONS AND DISCUSSION

Here we reflect on the benefits and difficulties in the design and delivery of this interdisciplinary teaching and learning material for the educators and the perceived benefits for the students. We link to the theories of interdisciplinary pedagogy outlined in the introduction and discuss what we might do differently.

Student and staff feedback

Whilst the numbers completing the survey were small, they were generally encouraging. The first of the Warwick student comments suggests the design achieved sufficient diversity and cohesion between the lectures. The second comment about the flipped lecture shows the flexible way in which the lectures can be used, according to the delivery mode. The challenge to include current examples is a valid one, especially difficult when delivering the part of the series which is outside the teacher's specialism (e.g. Barons delivering lectures 1-3). The module leaders both regarded the lecture series as beneficial and innovative.

Our own assessment is that the lecture series contributed meaningfully to the modules within which they were delivered. The multidisciplinary team design was quite different from what we had previously produced when each of us designed alone, and in the Warwick case, a one-hour guest lecture was expanded to two whole-day teaching seminars. One of the big advantages is that the video lectures are presented by specialists, which support authentic learning. The final comment is a reflection of the unfamiliarity of the students with Bayesian modelling. We agreed, on the basis of the survey, that it would be good to build up more slowly to the Bayesian Modelling element and to make even stronger links to the preceding material.

Design reflections

Monash students are being prepared for employment in multi-professional settings, so interdisciplinary learning is important contribution to their development.

The design of activity – discussion – reflect was one that was familiar to the students at both universities. Monash academics are familiar with this mode of delivery within their signature pedagogy. In mathematical sciences, signature pedagogy is a large lecture with new theory, followed by a problem set to try individually, followed by a small group support, so the discussion-based mode of delivery was much less familiar.

Since the graphical representation is of mathematics, the representation inherits some of the features that are important in mathematics: for example, the semantics of the representation are very precise and there are clear meanings associated with way the representation is drawn, in the case of Bayesian networks these are conditional probability statements. Mathematical theorems about BNs also impose strict precision on the interpretation of the network structure. This was hard for students to grasp.

Links to Theory

The iterative design, which reinforced previous material and extends understanding reflects the principles of instruction developed by Rosenshine and by Spelt *et al.*, specifically principles of iteration, phased, gradual advancement, and linear progression with milestone with encountering questions. This seemed to move the students along in their learning, with plenty of opportunities to understand at a deeper level.

Language

We see many elements of our practice already providing relevant support under Woods' helpful characterisation of interdisciplinary communicative competence. Preparation is given in introducing and repeating basic concepts in pre- and post- lecture material. Experience of interdisciplinary collaboration is provided, repeatedly, in the in-class tasks, allowing the cyclic engagement Woods (2007) describes, and post-class forum posts at Monash or (if selected) projects at Warwick provide reflection in interdisciplinary collaboration. There is room to develop these elements in a more intentional and explicit manner.

Curriculum design

As in (Klaassen, 2018), we analyse our case study retrospectively against the method of Repko for curriculum design; we were unaware of it at the time. We see that under the first heading, 'Design', our warrant for interdisciplinary education is that household food security is a complex problem requiring a complex, multi-faceted solution that incorporates the multi-actor interests in the space. 'Present', the rationale for interdisciplinarity, is that no-one can design effective policies without having foundational knowledge of nutrition and data science approaches. These are relevant disciplines (there are others) and the food security problem sits at the boundary of these ('identify') as disclosed by published literature and experts ('conduct'). Understanding of the relevant literature and research are made accessible by relevant experts ('develop'). Students create an integrated framework for tackling the problem under the guidance of mentors with interdisciplinary expertise ('study' and 'differences / similarities') and then use that framework to integrate relevant knowledge ('create') and 'combine' these through integrative assignments. Thus the nine elements are present, at least in some respect, in our design. Consideration of each in turn would be a useful exercise in developing further and renewing the lecture series.

Assuming that students can independently integrate multiple signature pedagogies is not evidenced, and a better approach would be to actively support recognition and navigation of disciplinary boundaries (Klaassen, 2018). This is not explicitly part of our series at present.

Others have found that the most enduring interdisciplinary initiatives have been related to the establishment and enhancement of interdisciplinary classes within existing degree programmes (Pharo et al., 2014). Our lecture series enhances established courses and looks likely to endure long enough to need a refresh of the research.

Assessment

It is challenging to recognise the full value of interdisciplinary training in assessment. Differing notions of excellence and assessment were not issues we faced, since the session we devised were a series of five to be delivered within modules which had other content. At Warwick at postgraduate level, there is some flexibility in the topics students can choose within their assessment, so the material in these sessions may be included, but is not mandatory. At Monash undergraduate level and postgraduate level these public health nutrition units are mandatory, assessment is by either assignment and/or by examination

Student benefits

Most challenges in our lived experiences do not sit neatly within the boundaries of our lives, but have social, emotional, financial, temporal and other aspects to them. Interdisciplinary teaching and learning fosters the ability to think in multiple ways aiding problem-solving and employability. Interdisciplinary education, occupying a 'third space' at the boundary of disciplinary groups, teaches students to be open to different perspectives (Klaassen, 2018). One student on an interdisciplinary course reflected:

> *It was often difficult emotionally, but it made me realise there were other ways of thinking about things*.

This kind of insight is the key to the value of interdisciplinary teaching and learning and creates graduates better able to navigate a pluralistic world.

Our students had cabaret style seating which facilitated discussion. In some cases, groups were mixed up part way through the session. The mixture of cultures brought a breadth of perspectives to the table discussion and all-class feedback, such as the balance between individual and government responsibility for household food security and the relative influence of those actors. For some students, the idea that it was possible to live in a high-income country, be in paid employment, and still go without food was a revelation. The discussion activities also helped students appreciate that different countries in the world organise things differently – in UK cost of health problems rarely springs to mind as a problem because there is healthcare free at the point of delivery. In other countries, the impact of health costs on household disposable income can be considerable and drive many into food insecurity and other forms of poverty.

At Warwick, students' familiarity with the materials in the first lecture seemed to make them feel like experts, whilst the speedy move into less familiar territory was marked with less confidence, in a classic Dunning-Kruger effect (Kruger and Dunning, 1999).

Language, especially the precision required in the mathematical sciences elements, continued to challenge students in the classroom.

Staff

Labour

As we set out to design teaching material that was truly interdisciplinary, rather than multidisciplinary, we experienced the additional labour, discomfort and frustration that interdisciplinary working brings, as described by Frodeman.

The numerous iterations required were facilitated by the opportunity to be in the same room for extended periods over several weeks. One challenge is that in preparing lecture materials, an educator has in mind a typical student, but neither of us had experience of the students the other would be teaching. The difficulties with language may have been the outworking of different mental models driven by our disparate signature pedagogies. Included in the consideration of language is visual language. Those who have the mathematical sciences as their home discipline easily interpret graphs, charts and diagrams, which may be mysterious to (or easily misunderstood by) the uninitiated. The challenge is whether to use alternative representations or to take the time to specifically explain the semantics of a disciplinary representation for those who may be unfamiliar. Being from different disciplines ourselves, we were able to interrogate each other's representations and give feedback on what was and was not intuitive or well-understood. These iterations helped us to think through how we might draw on the familiar to explain the new, given a variety of backgrounds. It was also necessary, since we would be delivering each other's material to our own students each year.

There was also the labour of coordination – we wanted just enough overlap between sessions that each lecture could stand alone, or refresh memories from last session, but not so much that it was tedious or patronising, conscious that the material we were producing could be used in different ways.

Recording a talk against a green screen was also very challenging; in most teaching or presenting situations (pre-COVID), a presenter responds to audience cues – in green screen there was no audience to respond to. In addition, our slides were on a very small laptop screen and so it was hard to see them clearly, as we recorded the presentations. This is a very different dynamic from presenting in-person. However, this also admits the possibility of updating the material as research moves on, retaining the authenticity of having subject specialists delivering material closest to their research focus.

Staff careers

There were no perceived disadvantages to interdisciplinary working in public health nutrition, as it is a multiprofession field. In mathematical sciences, however, the culture promotes pure, abstract work as of highest excellence. This is somewhat mitigated in the UK by the more favourable campus cultures called for by Klein and Falk-Krzesinski driven by government initiatives, such as the impact agenda. In addition, some Universities have broadened the remit for promotion and hiring beyond publications and grant income, although these remain important. For a mathematical scientist, a mixture of wholly mathematical sciences research with some interdisciplinary work could be a safe strategy.

CONCLUSION

The five-lecture series contributed meaningfully to the students' understanding of the complex problem of household food insecurity and interdisciplinary development and was designed consistently with current literature on interdisciplinary pedagogy. The survey, whilst limited, showed a general satisfaction of the student experience and the module conveners were complimentary. There was additional labour for instructors compared to preparing within their home disciplines, and this may have been uneven between pedagogies. It was always intended that the lecture material would be periodically refreshed to keep abreast of current research. This will be a good opportunity to consider more closely some of the theoretical matters outlined above.

ACKNOWLEDGEMENTS

The authors would like to thank the Monash Warwick Alliance Education Fund for enabling the visit of Barons to Monash which enabled this work to go ahead.

The authors would like to thank Warwick Food GRP for the contribution of additional funds during the visit.

The authors would like to thank Monash colleagues Claire Palermo and Julia McCartan for supporting the project and delivery of the teaching materials.

The authors would like to thank Warwick colleague Rosemary Collier for welcoming the new lecture series into the food security module at Warwick.

Martine Barons would like to thank Warwick colleague Jonny Heron who designed and delivers the Postgraduate Award in Interdisciplinary Pedagogy through the Institute of Advanced Teaching and Learning at Warwick.

Martine Barons would like to thank Warwick colleague Elke Thönnes for sharing experiences of interdisciplinary courses involving undergraduates from Warwick Statistics

The authors would like to thank the two anonymous reviewers whose insightful comments have improved the paper considerably.

Appendix

The survey:

QID92 - Which University do you attend?

QID93 - Is the course that you're enrolled in an Undergraduate or a Postgraduate course?

QID94 - What course are you enrolled in and within what subject are you completing this food security session?

QID95 - Within what discipline are you studying?

QID96 - Prior to participating in this session, how familiar were you with the following?

Food security

Systems thinking

Complexity Science

Bayesian Modelling

Likert scale: Extremely familiar, very familiar, moderately familiar, slightly familiar, not familiar at all

QID97 - Which of the 5-part teaching series have you completed?

QID98 - Thinking about your participation in all of these sessions, please indicate how much you agree with the following statements:

The learning objectives were all addressed within the session

The video presented a clear, succinct and evidence based overview of the topic

The facilitator guided class discussion effectively to address learning objectives

The time spent on this topic was not too short or too long

The content of these sessions can be applied to my other areas of study

Q8 - Any further feedback ?

Table 1: Students' prior familiarity with key concepts

Question	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
Food Security	13.3%	40.0%	40.0%	6.7%	0.0%
Systems-thinking	0.0%	0.0%	53.3%	40.0%	6.7%
Complexity Science	0.0%	6.7%	33.3%	26.7%	33.3%
Bayesian Modelling	0.0%	0.0%	20.0%	13.3%	66.7%

Table 2: Students' satisfaction with learning objectives

Question	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The learning objectives were all addressed within the session	40.0%	46.7%	13.3%	0.0%	0.0%
The video presented a clear, succinct and evidence-based overview of the topic	40.0%	40.0%	13.3%	6.7%	0.0%
The facilitator guided the class discussion effectively to address learning objectives	46.7%	33.3%	20.0%	0.0%	0.0%
The time spent on this topic was not too short or too long	26.7%	33.3%	40.0%	0.0%	0.0%
The content of these sessions can be applied to other areas of my study	46.7%	33.3%	13.3%	6.7%	0.0%

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