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What's the risk of disease? Software tools to support learning concepts of risk perception and assessment

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Risk assessment for human and animal diseases is performed to clarify pathways that may result in disease, and estimate the likelihood of this outcome in specific settings; the outputs are typically used to inform decisions and support policy development. It is often performed using a structured process of elicitation of opinion from subject experts, which aims to minimise the inherent element of uncertainty due to the subjective nature of elicitation. User-friendly software tools can generate insights into risk perception of assessors, elicitation of expert opinion and quantitative estimation of risk. Such tools were incorporated into an online postgraduate course on risk analysis delivered to 36 veterinarians across South Asia. The activities developed to apply these tools required careful staging and scaffolding within the course framework. They highlighted the importance of good coordination and effective communication between the assessors, as well as with the course tutors.

Keywords: risk analysis; risk perception; cognitive maps; network analysis; online learning.

Introduction

The rate of emergence and global spread of new, highly infectious diseases such as severe acute respiratory syndrome (SARS), avian influenza (H5N1) and H1N1 influenza is accelerating (Jones et al., 2008). A common feature of these diseases is that they originated in animal populations before crossing the species barrier to infect humans. Timely identification of such novel infections is essential to implement measures for preventing their spread. This can be challenging for a number of reasons. Firstly, differentiating such new infections from known infections can be difficult, especially if the symptoms are quite generic ("flu-like"). Secondly, their diagnosis requires the presence of suitably skilled human and animal health professionals, as well as adequate facilities and resources. A third prerequisite is the effective coordination between public health and animal health professionals, within as well as between countries. The rapid globalisation of diseases such as SARS and H1N1 influenza has exposed shortcomings in all three of these areas. This has mobilised substantial investment to increase capacity. A key perceived need is the strengthening of cross-sectoral collaboration between doctors and veterinarians, an approach known as 'One Health' (Zinsstag et al., 2011); the foundation of effective action begins with education (Conrad et al., 2009; Osburn et al., 2009).

In 2010 Massey University launched a ‘One Health’ programme in Asia to strengthen the management of current and emerging human and animal diseases (Vink et al., in press). This programme provides formal training of public health doctors and veterinarians through two Masters degrees: a Master of Public Health (Biosecurity) and a Master of Veterinary Medicine (Biosecurity). The first cohort of students, who commenced their studies in May 2010, consisted of 70 doctors and veterinarians with relevant experience in disease control activities from Afghanistan, Pakistan, India, Bangladesh, Nepal and Sri Lanka. Equal numbers of doctors and veterinarians were enrolled, the objectives being a) to strengthen technical capacity, and provide a unified epidemiological lexicon, b) to foster interaction, communication and active collaboration between the professions and between the participating countries, c) to establish an effective professional network that will be able to bring into practice the principles of ‘One Health’, and d) to improve the candidates’ competence at using information and communication technologies, and confidence in working in an online environment. The Masters programmes require completion of eight courses, as shown in Figure 1. Seven of these are taught entirely online, using the Moodle Learning Management System (LMS) (Moodle, 2012); the remaining course (the fourth of the foundation courses) is a combination of online and face-to-face training. The first four courses provide a foundation in epidemiology and are common to both degrees. The remaining four courses address specialised topics related to human or animal health.

This paper presents a selection of interactive learning activities that were integrated into the veterinary specialty course entitled “Risk and Decision-making During Disease Outbreaks” (Figure 1). In the subsequent section, we will summarise the aims, pedagogical considerations, design and structure of the course. This will be followed by a description of three specific activities, successively defining the objectives, implementation and outcomes of each. The paper will conclude with a general discussion on how these activities contributed towards achieving the course aims.

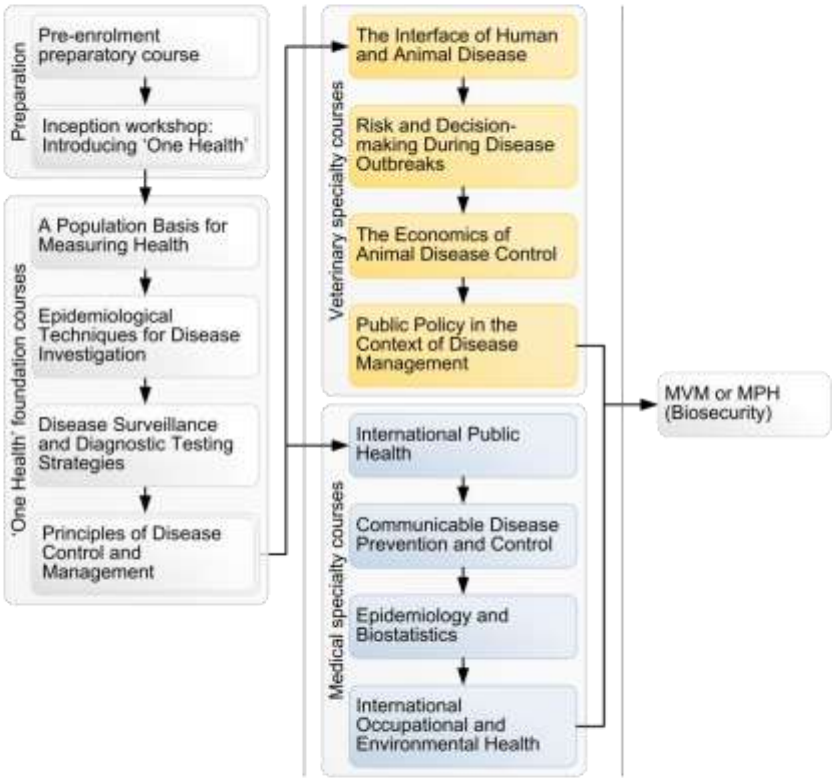

Figure 1: Programme structure of the MVM (Biosecurity) and MPH (Biosecurity) programme. The activities described in this paper fall within the second course in the sequence of veterinary specialty courses, “Risk and Decision-making During Disease Outbreaks”.

Considerations informing course design and structure

Risk assessment is performed for human and animal diseases to clarify and quantify pathways that may result in disease, and estimate the likelihood of this outcome in specific settings. The outputs are typically used to inform decisions for the management and control of disease. In analogy with evidence-based medicine, the risk assessment process strives to make use of the most reliable and current knowledge. We can distinguish between explicit knowledge (which is recorded or quantified) and tacit knowledge (which is individual and experiential) (Sandars and Heller, 2006). As the amount of available explicit knowledge on which to base an assessment of risk is often limited, structured techniques have been developed to incorporate the tacit knowledge held by "subject experts". This conforms to the social constructivist view of knowledge, which holds that the knowledge base used for decision-making is not static, but is constantly being expanded and augmented by information-sharing and incorporation of tacit knowledge. This is an integrative process: learners are actively attempting to "update" meaning (Siemens, 2005) and are "learning by doing" (Harasim, 2000). The constructivist theory has led to the concept of "communities of practice" consisting of individuals or members who actively contribute to and expand this collective knowledge base. Such communities can be formally or informally structured, and can meet face-to-face or virtually (Sandars and Heller, 2006).

The course aims were to enable students to formulate risk pathways that may result in disease, estimate the likelihood of this outcome, and utilise these outputs for decision-making. A key objective of the course design was to implement "active" modes of learning which encouraged small-group work and active collaboration. Thirty-six students from Bangladesh, India, Nepal, Pakistan and Sri Lanka were enrolled and grouped into six groups with as diverse a membership as possible in terms of nationality, professional experience and ability. This strived to foster a sense of community of practice, which is reflective of the environment within which risk assessments are carried out in reality. One tutor supported each group when they undertook specific activities; at other times the course coordinator (the second author) provided student support. She also oversaw the delivery of the course, and was involved with overall course assessment and evaluation.

The course was delivered online over a six-week period with a study load of about 20 hours per week. All study materials were made available in the Moodle course, including readings and resources; in addition, all students had full access to the Massey University library. Intensive use was made of native Moodle functionality to perform a combination of individual and group work, including discussion forums, lessons, quizzes and questionnaires. To carry out the specific risk assessment exercises, use was made of additional software tools which were embedded as seamlessly as possible into the LMS. As the course was delivered over a compressed time period, the sequence of content and activities was quite rigidly staged. To ensure students could plan for and engage in the synchronous and asynchronous group activities, they were informed of key calendar dates one month before the course started, and upon course commencement were presented with a clear 'roadmap' that outlined activities and assessment dates. Assessment consisted of a combination of individual and small-group outputs. The main assignment (50% of the course total) consisted of an individual risk assessment performed by the student on a topic of his or her own choosing, applying the techniques taught in the course. The activities described below counted for a total of 30%, with the remainder made up of quizzes and the student's participation in the small-group activities.

Course activities

Three specific activities are described in this section. Each made use of a specific software tool. The activities represented a logical sequence, namely:

- Ranking of disease hazards and agreement between assessors, to illustrate the importance of discussion for overcoming ambiguities in individual risk perception.
- Cognitive mapping of a disease outcome, to illustrate differences in perception and outlook, even when developed as a group, that is, that different "communities of practice" will reach different endpoints.
- Formal specification of a risk model, to quantify the likelihood of a disease outcome under different conditions.

The first two activities were performed in groups, while the third was individual.

Risk ranking and risk matrix development

Definitions and objective
The central concept of a risk matrix is that the likelihood and consequence of disease events are individually scored on a discrete scale by a number of assessors. These descriptors are then used to quantify the level of risk. When repeated for different disease hazards, the hazards can be ranked by risk, and the variability of the risk scores between the assessors can be measured. As the categories on which the scales are based are descriptive, this process is qualitative. This can hinder interpretation, reducing the level of agreement; a process that is referred to as linguistic uncertainty (Regan et al., 2002). Typically, several rounds of risk scoring and discussion are needed to satisfactorily deal with the problems of language and interpretation.

The objectives of this activity were to emphasize problems associated with myopia and overconfidence in performing risk analysis, and to instil an appreciation of the capacity of communication and discussion to buffer against these problems. This demonstrates that it is unwise to rely on the perception and tacit knowledge of the individual, and that even within a group, an iterative process is required to refine the analysis.

Implementation

The activity was structured in a similar fashion as described by Carey and Burgman (2008). In a questionnaire in Moodle, students were asked to qualitatively estimate the consequences associated with eleven infectious animal diseases. Each disease was assigned a numeric score ranging from 1: Insignificant to 5: Catastrophic. Subsequently, the students were asked to estimate the likelihood of these diseases occurring, ranging from 1: Rare to 5: Almost certain. The results were compiled into a risk matrix using Subjective Risk Assessment, a Flash-based tool (Australian Centre of Excellence for Risk Analysis, 2012). Outputs for each group were made available, including a correlation matrix, which measured the level of agreement between each pair of students in the rank order of risk posed by the eleven disease hazards (Figure 2) and a hazard ranking graph, which ordered the disease hazards by magnitude of risk while also displaying the variability of the responses for each disease (Figure 3).

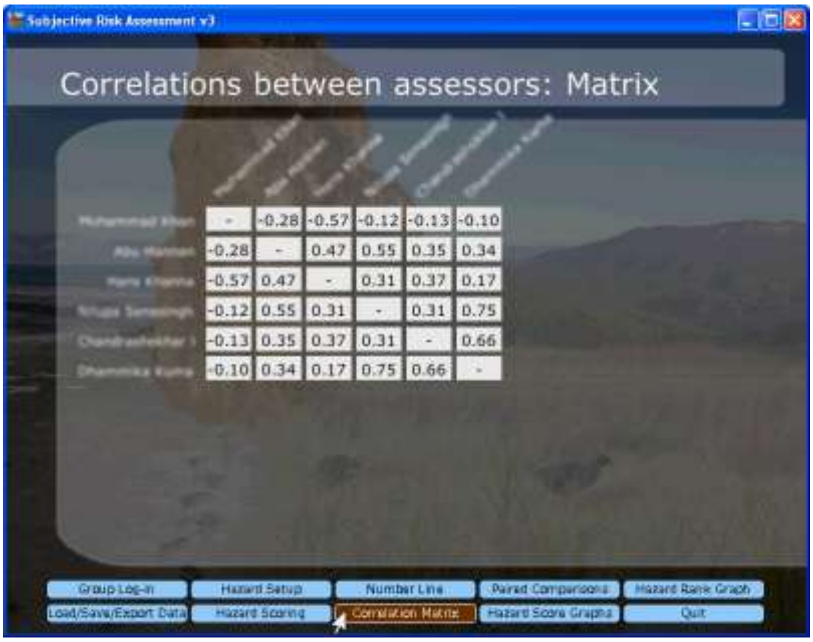

Figure 2: Screenshot of the Subjective Risk Assessment interface, showing the rank correlation matrix between six students in one student group. The scores range from 1 (perfect agreement in rank order) to -1 (complete disagreement), with 0 indicating the level of agreement that could have arisen purely by chance.

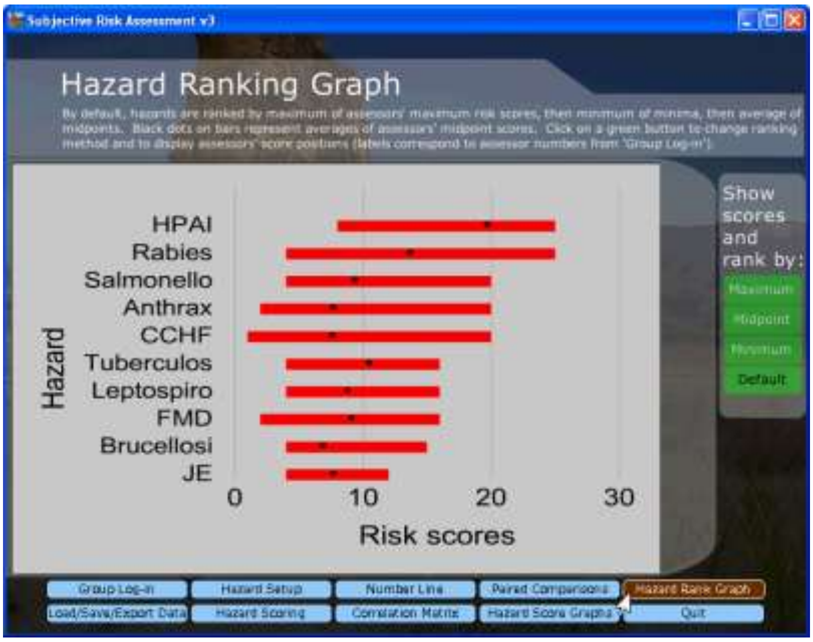

Figure 3: Screenshot of the Subjective Risk Assessment interface, showing the hazard ranking graph for the top ten of eleven diseases of one student group.

In a grouped Moodle discussion forum, students were asked to interpret and discuss the results. They had the opportunity to directly discuss their scores with whomever showed poor agreement to themselves. Subsequently, the sequence of steps was repeated to assess the consistency of the ranking, and whether the agreement between the students had improved.

Students attributed poor agreement entirely to the fact that groups included members from different countries within South Asia, representing a diverse range of backgrounds. To show that these factors could not explain all the variability, the responses of the two questionnaires were also used to generate five country risk matrices.

Outcomes
The level of agreement in the first round of assessment was generally poor; there were substantial differences in the risk rankings of the disease hazards, as well as in the variability in the perceived risk of each hazard.

In the discussions that followed in the Moodle forums, the six groups generated 187 discussion threads with over 300 comments posted over a four-day period. However, while the hazard rankings in the second round of assessment were somewhat more consistent, and the within-group variability did decrease, the magnitude of the effect was not substantial. For the country-level groups, the students expected the rankings to be more consistent than the regional groups, with smaller variability; this was not the case.

In summary, no clear patterns emerged. This result can be primarily attributed to linguistic uncertainty (Carey and Burgman, 2008), that is, uncertainty arising from inconsistent interpretation of words, or different or imprecise meanings of words. This was alluded to in the discussions, in which students mentioned that they found it difficult to assign scores to consequence or likelihood in such a general context.

Cognitive mapping of a disease

Definitions and objective
Cognitive maps, which were introduced in the 1970s by Robert Axelrod (1976), are graphical tools for organizing and representing knowledge, and reflect a ‘narrative’ of cause and effect (Novak and Cañas, 2006). They are directed graphs in which nodes represent key concepts, and interconnecting edges represent causal relationships. They are developed following a process of elicitation, which involves selecting relevant concepts, and specifying the direction and sign (positive or negative) of the associations between the selected concepts (Maule et al., 2004). Cognitive maps have been extensively used in education, including in the medical field (Pinto and Zeitz, 1997; Cañas et al., 2003). In medical education, they were found to assist learning for causal mechanisms in the development of disease (Kumar et al., 2011).

In the context of disease causation, it is customary to define an outcome (disease) and putative factors which influence the risk of this outcome occurring. Cognitive maps can effectively visualise the complex and dynamic processes that lead to disease, incorporating factors which are directly related to the outcome (e.g. an infectious agent) as well as factors exerting more indirect effects (e.g. social, cultural and economic drivers). As a consequence of inherent differences in perceptions and outlook, it is inevitable that different people will construct different cognitive maps for the same problem, even when presented with a common set of defined concepts. Elicitation within a community of practice representing multiple stakeholders draws on collective insights, knowledge and experience: this can improve and prioritise exposure pathways. The collaborative nature of elicitation can reconcile different perspectives and reduce linguistic misunderstanding through clear articulation and communication of causal pathways.

The objective of this exercise was to demonstrate that, even when constructing cognitive maps for the same outcome and starting with the same set of factors, and communicating in real time rather than asynchronously, there is substantial variability in the final maps produced; in other words, that the communities of practice represented by the groups had developed distinct ideas and perceptions.

Implementation
This activity was performed as a combination of small-group and individual activities. The disease chosen was rabies, at it has serious implications in human and animal populations, and is prevalent throughout the region in which the course was taught. Consequently, all students had good understanding and knowledge of the disease. Use was made of the IHMC CmapTools software (Institute for Human and Machine Cognition, 2012). A CmapServer was installed on a web server at Massey University, and used to develop the cognitive maps. The students downloaded and installed CmapTools on their laptops, and connected to the CmapServer (Figure 4).

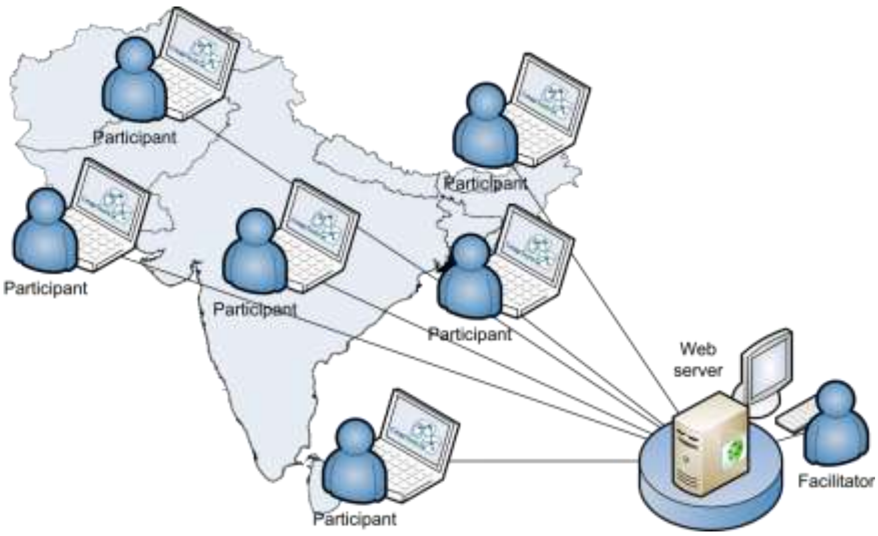

Figure 4: Schematic diagram of the cMapTools activity. One facilitator mediated two synchronous sessions with an average of six participants from throughout the region.

Each of the six student groups could access a folder on the server (Figure 5), which contained a cognitive map containing an outcome node (a human case of rabies, shaded black), and a "parking lot" of concepts: 20 or so risk factors (shaded blue) and six management interventions (shaded green). The maps were developed by the groups using the IRC facility which enabled synchronous collaboration. At appointed times, the students accessed their group map to discuss its development. The group tutor moderated the discussion and followed the lead of the students to construct the map, using the available concepts. To avoid excessive complication, groups were asked to include no more than two management options and six to eight factors. Groups had the option of defining any missing concepts, if they considered these to be essential to discerning the merit of alternative management interventions. The cognitive maps were developed in two sessions of up to two hours each.

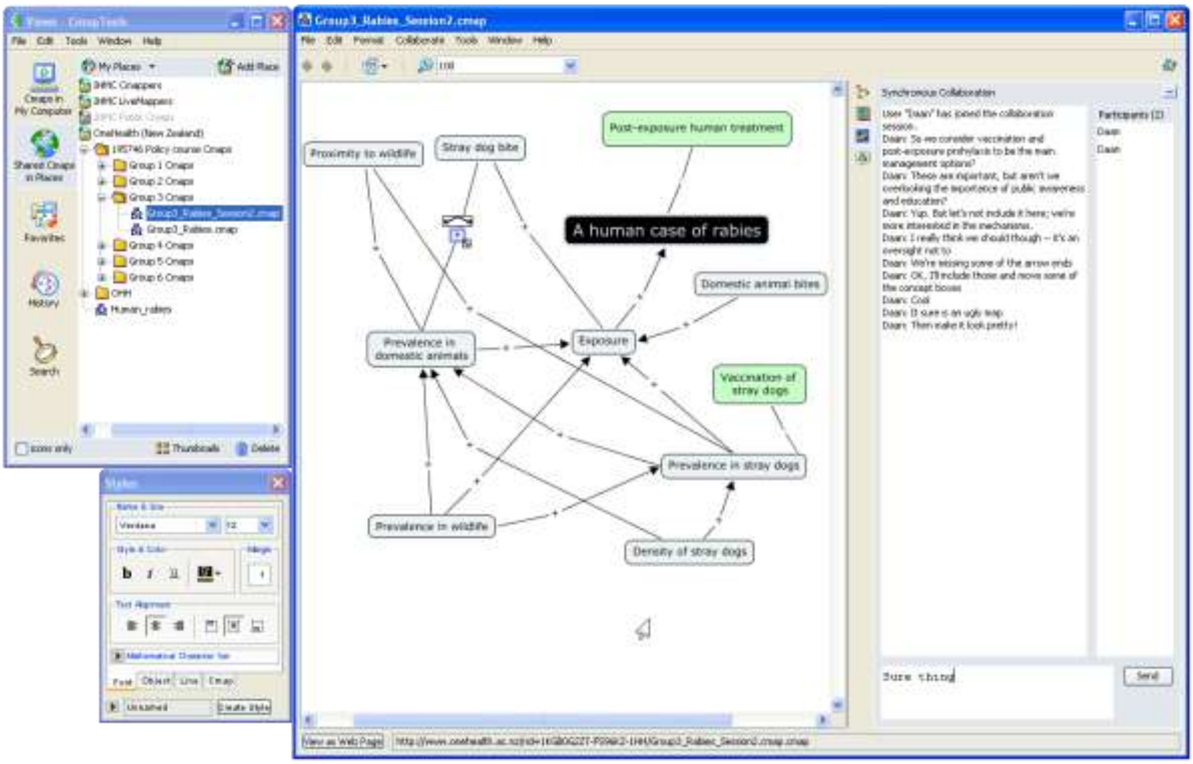

Figure 5: Screenshot showing the cMapTools interface, including the location of the server (left top), formatting dialog (left bottom), main user interface (main panel) with real-time IRC.

After finalisation of the maps, they were uploaded and shared to all students. As part of their assessment, students were asked to constructively review the output of one other group.

Outcomes

As expected, there were substantial differences between the cognitive maps produced by the six groups, in terms of the overall structure (which included linear and hierarchical causal pathways and maps characterised by high interconnectivity and multiple feedback loops) as well as in the number and selection of concepts chosen. The activity was effective in that it demonstrated the variability between groups; it did help to structure thinking, leading to the definition of exposure pathways and mechanisms; and restricting the number of concepts stimulated discussion on which interventions and risk factors to prioritise.

Constraints of this activity included the logistic requirements (installation of CmapServer, setting up for the activity, providing detailed and accurate installation information to the students); the time differences between New Zealand and the five countries; and limitations in internet connectivity, which made participation very difficult for a small number of students.

CmapTools was voluntarily utilised by students in successive courses in the programme, in different assignments; this indicates that the software was considered user-friendly and insightful.

Quantifying risk by specification of a probabilistic model

Definitions and objective

The methods and models considered up to this point were qualitative in nature, or relied on qualitative inputs. As described above, cognitive maps can provide a loose structure for articulating perspectives and pathways. In addition, they can provide a visual model which can form a basis for the specification of a quantitative model, i.e. one in which the inputs and outputs are expressed numerically (Maxwell and Buede, 2003; Mingers and Rosenhead, 2004). The objective of this third activity was to introduce one method of specifying a quantitative model. Such models can easily become mathematically complex. However, the software used for this activity enabled graphical specification of the relationship between variables. This was followed by entry of input values; the software then computed the output value.

Implementation

As the objective was to familiarise the students with the software, this activity was implemented in Moodle as an individual lesson, rather than as a group activity. The starting point was a simplified cognitive map representing the relationship between several concepts and the occurrence of a human case of rabies (Figure 6).

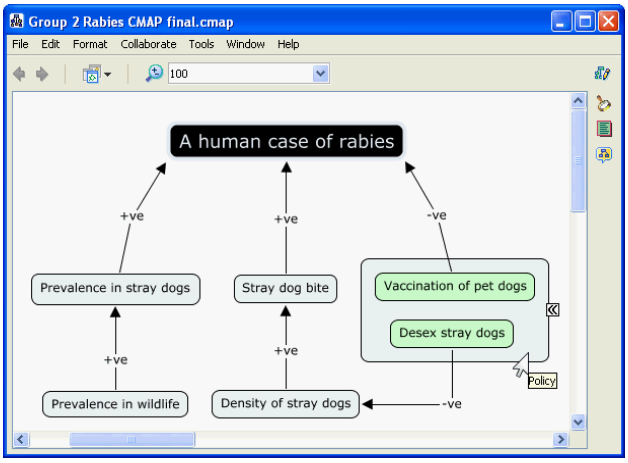

Figure 6: Simplified cognitive map which was used as a basis for quantifying the risk probabilities.

The activity made use of specific software called Netica (Norsys Software Corp., 2012) which enabled the students to replicate this cognitive map, and assign probabilities to the levels of each concept (Figure 7). The software used probability theory to estimate the likelihood of the outcome (a human case), for each of four policy conditions under consideration. All input values were given. Students were asked to update the model by altering parameters and recalculating the estimated outcome.

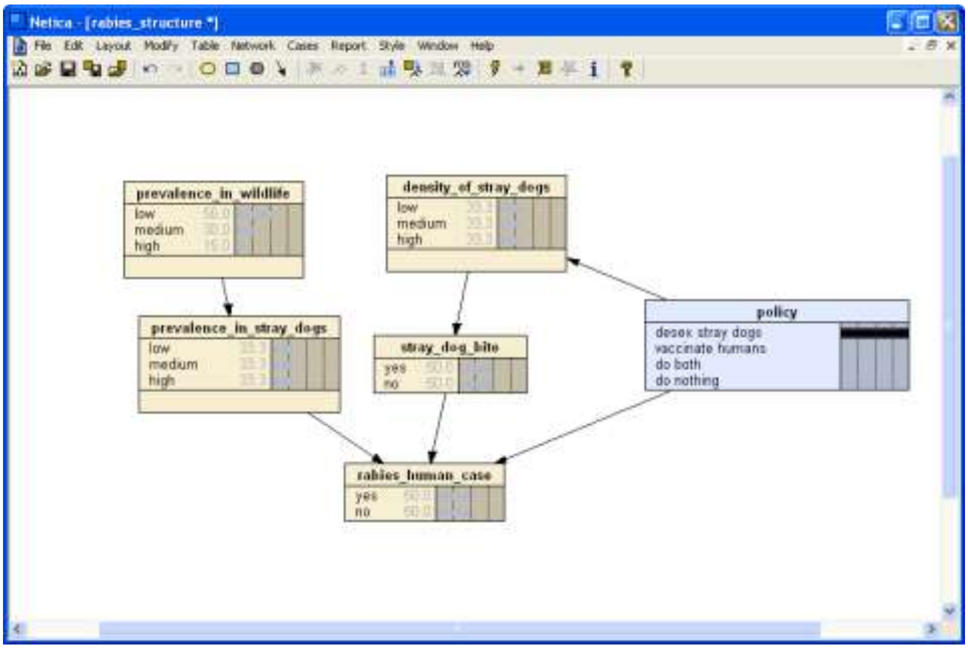

Figure 7: Screenshot of the Netica user interface, showing the network of factors leading to the outcome (human case of rabies). The blue node represents a decision node: for each of the four policy options, the likelihood of an individual person contracting rabies is estimated, given the estimates entered for the other factors.

Outcomes

As this activity illustrated a more advanced concept, it was incorporated into the course as an individual activity, and successful completion was not assessed. However, it was felt to be relevant for inclusion as it

- introduced the students to quantitative methods for risk assessment;
- extended the more advanced students; and
- allowed students with a specific interest in this field to benefit from this ‘state of the art’ material.

General discussion

Establishing this Master degree programme was challenging from a number of perspectives. Firstly, developing a programme tailored to the evolving and fast-developing concept represented by ‘One Health’ meant that the curriculum and the course content had to be designed and built from the ground up. Secondly, online learning was a new experience for almost all the South Asian students, the teaching model was unfamiliar to most, and a large range in the students’ pre-knowledge and experience needed to be accommodated.. Thirdly, the technical aspects of delivering online distance education into a region with highly variable internet availability required careful consideration.

The concept of ‘One Health’ is, by definition, highly multidisciplinary, spanning human, animal and environmental health. In spite of its complexity, support for this concept has grown exponentially in recent years. One reason for its appeal is that it explicitly aims to counteract the divergence of the human, animal and environmental health professions arising from increasing specialisation. Consequently, the leading objectives of this programme were to establish a consistent lexicon and mastery of relevant competencies. Key strategies to achieve this were to teach into a common learning space, and to establish effective communication and collaboration between students from the different countries. A consistent approach for bringing this into practice was the incorporation of relevant, engaging and multifaceted case studies, which required completion of a set of interactive activities, where applicable in a small-group setting. Students were encouraged to make the best possible use of various information domains, including traditional sources such as the University library, but extending to the internet as well as the knowledge and experience held by the participating students themselves. Our experience has been that online learning lends itself organically to the ‘One Health’ approach: De Laat et al. (2006) comment that the field of networked learning, too, is increasingly interdisciplinary and draws upon theoretical perspectives from the domains of education, the social sciences, computer sciences and linguistics. Sandars (2009) succinctly reviews the changing needs and competencies required for the medical learners of the future, and endorses Siemens’ (2005) approach of ‘connectivism’ as a means of identifying and linking information from multiple sources into a dynamic personal knowledge base.

In the risk assessment course presented in this paper, human and animal rabies in South Asia was chosen as an appropriate case study due to its regional relevance and impact. The learning activities that were developed made use of several software tools embedded into the LMS to facilitate the application of the analysis of risk. These activities consisted of a mix of small-group and individual work; a key objective was to establish groups of students from a wide range of countries, professional expertise and experience as “communities of practice”. As there is a relative paucity of verifiable information (explicit knowledge) on the case study in question, this approach was especially important to utilise the tacit knowledge held by these groups for the risk assessments. In addition, this approach closely reflected the sequence of techniques which is followed when risk assessment is performed in actuality, and thus presented a learning experience that was intended to feel “real”. By following this natural sequence of steps, we could demonstrate and highlight constraints and limitations. The first exercise in subjective risk analysis was designed to illustrate the importance of discussion for overcoming ambiguities in language and individual risk perception, and overconfidence in individual opinion. Subsequently, developing cognitive maps as a group activity emphasized the differences in perception and outlook between groups or “communities”. Using a simplified cognitive map as a starting point, the specification of a formal risk model showed how the likelihood of a disease outcome could be quantitatively estimated.

A number of additional activities were incorporated into the course, but were omitted from this paper. For instance, after the specification of the quantitative model, a master class in the elicitation of expert opinion, using a Delphi technique (Linstone and Turoff, 2002), was organised as a teleconference. In two facilitated sessions, panels of eight to twelve student “experts” strived to reach a consensus of opinion on five key questions related to rabies. The scenario was set in a country from which there were no students (Bhutan), to ensure that no students considered themselves to be more highly qualified than others.

To implement the activities within this course over the six-week period of delivery, careful staging within the course framework was required, as well as providing appropriate scaffolding to individual students. This relied on clear communication and effective coordination on between the course tutors and students. The use of the software tools was very highly rated in the course evaluation questionnaire, although a number of students found the subject and content challenging. In addition, the collaborative nature was appreciated, particularly the synchronous group communication sessions. The largest constraints stemmed from difficulties in communication. Firstly, limitations in internet connectivity, speed and reliability made it difficult for a number of students to participate fully in the synchronous sessions. The second constraint was language-based: it was evident that linguistic uncertainty not only applied to risk-related concepts, but also extended to some students' ability to perform the activities! From the submitted individual assignments, it was clear that most students had grasped the fundamental concepts of risk assessment, and a number submitted excellent assignments. Three students failed the course, due primarily to insufficient time spent studying rather than a lack of ability.

Conclusion

The software tools described in this paper have been successfully used for teaching risk assessment in a face-to-face delivery mode. However, integrating the combined set of these tools coherently into a fully online learning environment, and supporting this with the native functionality of the LMS to facilitate learning, extended the utility of these tools and enabled students to understand the contexts in which they should be applied. This enabled 'state-of-the-art' techniques in the field of risk analysis to be easily incorporated into the course.

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