JISC DESIGN FOR LEARNING PROGRAMME

CONSTRUCTING2LEARN PROJECT

EVALUATION REPORT

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JISC

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1. INTRODUCTION

The Constructing2Learn (C2L) project was carried out by a team from Oxford University Computing Services as part of the JISC Design for Learning (D4L) programme from May 2006 to December 2007.

Computer-based modelling is playing an increasingly important role in scientific topics as diverse as ecology, epidemiology, economics, sociology, animal behaviour, and climate. There is a growing awareness that university students in these fields need to learn how models are built and how they work, and yet they do not typically have computer programming skills. The C2L project aimed to remedy this by developing a tool that enables students to build models by composing high-level pre-built components, by integrating the tool with a learning activity management system, and by creating and trialling a few computer model construction learning designs.

The goal of the project was to support teachers and students in the building of models in the social and life sciences. We developed a modelling tool called the BehaviourComposer that students without prior computer programming experience could use to build, execute, and analyse serious models in their subject of study. We integrated the tool with LAMS 2.0 and built a few LAMS sequences and two activity designs that were used in our evaluation sessions. so that learning designs that included use of the BehaviourComposer could be authored, executed, and monitored within that environment.

(Adapted from the project completion report.)

2. METHOD

2.1 Research questions

The project had both technological (developing the BehaviourComposer and the LAMS engine) and pedagogical aims. The evaluation concentrated on the pedagogical aims and on usability, investigating these two dimensions.

We did not have access to appropriate data from comparable existing modelling activities, so were unable to make comparisons between tasks performed with and without the BehaviourComposer.

Our original research questions were:

1. Pedagogical value of the BehaviourComposer

1.1 From the tutors' perspective

1.1.1 Does students' use of the BehaviourComposer to build models:

- Result in robust, comprehensive yet parsimonious models that demonstrate understanding of the domain and the behaviour of the agents/phenomena within it?
- Demonstrate effective model-building strategies (or at least make those strategies evident to the tutors for critique and feedback to the students)?
- Enable competence in programming?

1.1.2 What pedagogical value is to be accrued from the sharing of models, and in particular the inspection , running and critiquing of another student's model, whether or not this models the same set of phenomena?

1.2 From the students' perspective

How acceptable is the BehaviourComposer to students in terms of:

- Ease of learning to use and perceptions of cost-benefit of doing so?
- Mapping of the agents and behaviours in the BehaviourComposer to the agents and behaviours in the domain: comprehensiveness, scope, terminology?
- Ease of coming to grips with the programming concepts required to build meaningful models of the domain?
- Enjoyment of building, running and sharing their models?
- Sense of having benefited their learning through participating in this activity? (What aspects of learning? Programming skills, strategies for modelling, nature of the domain?)
- Motivation to use it again? (i.e. has it lowered the barrier to modelling using programming?)

1.3 From the research team's perspective

- Overall, what does the experience of the C2L project tell us about the relevance of such model-building tools in HE?
- Proof of concept: What development trajectory for the tool is indicated in the evaluation data from tutors and students?

2. Usability and utility

2.1 Focusing on the key activities outlined above, we wanted to determine the extent to which the BehaviourComposer met the following usability criteria:

- **Learnability:** How easy is it for users to accomplish the basic tasks the first time they encounter the BehaviourComposer?
- **Efficiency:** Once users have learned to use the BehaviourComposer, how quickly can they perform tasks?
- **Satisfaction:** How pleasant is it to use the BehaviourComposer?

2.2 Utility is related to functionality, and the key (two-part) question here was:

- Does the BehaviourComposer do what tutors and learners need? If not, what additional aspects of the worlds to be represented and/or what additional user tasks does it need to support?

In practice, however, the scope of these research questions had to be curtailed for two reasons. First, the two tutors who initially collaborated with the project team moved to other universities. Second, few subjects in the Oxford curriculum require students to undertake the kind of modelling supported by the BC, and with an already intensive workload, it proved difficult to secure time for more than one session with each group students. Thus, despite the interest in the BehaviourComposer shown by a number of teaching staff[1] the evaluation was largely restricted to the questions of usability from the students' perspective listed under research questions 1.2, 2.1 and 2.2, with the addition of pedagogic questions formulated by the tutors themselves – who, we should remember, were also experimenting with the BehaviourComposer as a possible solution to specific challenges.

2.2 Participants

The participants in the evaluation were two groups of students at Oxford University and their tutors:

- Master's students in the MBA and MSc Management Research programmes
- Third-year undergraduate students in the Department of Zoology

2.3 Evaluation events

Three evaluations were organised as follows:

Dates	*Student cohort*	*Model created:*
April-May 2007 (2 events)	Postgraduate students studying an elective module in complex systems for the MSc in Management Research or the MBA	Sugarscape (Epstein & Axtell, 1996)
October 2007 (2 events)	Third-year undergraduate students in the Department of Zoology	The spread of infectious diseases
May 2008 (2 events)	Management Research students as above	Sugarscape

Each event consisted of a hands-on session lasting approximately two hours. Students attended one session depending on their availability at the times offered.

[1] See the reports of meetings on the project wiki at http://dfl.cetis.ac.uk/wiki/index.php/Constructing2Learn#Summary_of_meetings.

3. THE "SUGARSCAPE" MODELLING SESSIONS

3.1 Background to the "Sugarscape" sessions

"Sugarscape" is an artificial world with life, death, wealth, sex, culture, trade, and disease described in *Growing Artificial Societies* (Epstein & Axtell, 1996). The model which formed the subject of these evaluation sessions focused on life, death, and wealth (covered in chapter 2 of the book).

The initial Sugarscape sessions were run in April-May 2007 as part of elective modules taken by students on the MBA and the MSc in Management Research at the Said Business Business School, University of Oxford. Students on these courses come from a variety of backgrounds, and so the evaluation captured demographic data in case it was possible to identify correlations between their previous experience (e.g. whether they had done any computer programming) and their response to the BehaviourComposer.

Because of the delay in the production of this report, we were also able to include a session run in May 2008 in our analysis.

3.2 Pedagogical aim of modelling Sugarscape

(This information was obtained during a meeting held with the tutor to plan the "Sugarscape" sessions.)

3.2.1 Management Research students: Complex Systems module

The MSc in Management Research is intended to prepare students for academic research. The normal method of teaching is eight 2-hour sessions per term. For the Complex Systems module, the tutor normally lectures for 1½ hours, with the remaining half hour taken up by a pre-prepared case study presented by students working in twos and threes. In terms of modelling, the tutor's aim is to give students a sense of what the different methods of modelling can deliver. However, there is only time in the MSc course for a brief overview; if students want to use a method in their research, they will have to do extra reading and studying. The tutor's approach thus involves very little hands-on experience of modelling – a less-than-ideal situation in which students risk acquiring misleading meta-theoretical knowledge and misconceptions. Therefore, in 2007 the tutor had been trying to push for opportunities for students to look at simple models, with Sugarscape as the starting point (session 2). He felt that it was unfair to make students write program code, and so the implementing the model in the BehaviourComposer would enable the students to assemble it more easily.

3.2.2 MBA Students: module in Managing Complexity: Financial Markets, Business Strategy and Innovation Networks

This elective module was first presented in 2007. Its curriculum differed from Complex Systems in the inclusion of sessions on financial market complexity at the expense of biology-related subject-matter and the detailed exploration of methodological and philosophical aspects.

The MBA students differ from the Management Research students in that they are more mature: some already have PhDs and/or 5-6 years' work experience. They may never have to do any modelling themselves in their work lives, but may work with people who do. Therefore, the aim is for them to gain an understanding sufficient to know: e.g. what sorts of questions they can/should ask of models and what sorts of critical judgement they should be making.

3.3 Method

3.3.1 Research questions

Based on his belief that the only way to understand models in depth is to engage in modelling oneself, the tutor formulated the following research questions with respect to the Sugarscape sessions:

1. What method(s) of modelling are feasible, and to what level of complexity can one go, given:
   a) Students' heterogeneous backgrounds?
   b) The time constraints imposed by the Oxford course structure?
2. What levels of support are necessary?

He aimed to assess students' learning through their subsequent work: i.e. assignments, also the case study presentations (both the presentations themselves and the kinds of questions that the other students ask the presenters).

3.3.2 Data collection methods

Our primary method of collecting feedback was through an online survey of the students, to be completed at the end of the session. In addition, we wanted to collect as many models as we could for the project manager to investigate, but these were not analysed as part of the evaluation.

The survey is included in the Appendix. Identical questions were asked in both 2007 and 2008, with the exception of an additional question in 2008.

3.3.2 Management research students - 2007

The Sugarscape session was originally planned for the second week of term; however, circumstances beyond our control meant that it had to take place before the formal start of term: i.e. before the students had received a proper introduction to modelling and before they had done the necessary background reading on the model.

The session took place in a lecture theatre with students using their own laptops. In all, 19 students attended, 17 of whom brought their laptops, necessitating some sharing. The format was:

1. Introduction by the tutor to the concept of agent-based modelling and to Sugarscape (10 mins.)
2. Presentation by the C2L project manager and assistance with downloading and installing the software needed for the session (20 mins.)
3. Introduction to the BC by the C2L project manager, using a LAMS sequence (20 mins.)
4. Modelling task by students: create the Sugarscape model using a worksheet for guidance and an answer sheet in case of problems (85 mins.). The worksheet is included in the Appendix.
5. Completion of online questionnaire by students (15 mins.)
6. General discussion (15 mins.)

3.3.3 MBA students - 2007

This session took place in the second week of term – i.e. after the students had already had two sessions on modelling – and was additional to the timetabled classes. Moreover, the tutor was

not present, and so the project team was responsible for leading it. The format was roughly similar to the first session, but without the tutor's introduction. Only four students attended.

3.3.4 Management research students - 2008

This session took place after the start of term, and followed a similar format to the 2007 session, with the difference that students had already studied the module for two weeks. The students worked with a version of the BehaviourComposer that had been rewritten as part of the successor project to C2L, Modelling4All (see page 24). Although the functionality was similar to the previous version, the interface in which the students built their model was markedly different.

3.4 Results

The following is a summary of the data from the online survey completed by the students. The data combines all three groups of students, on account of a) the small number of MBA students attending in 2007) and b) lack of substantial differences between the 2007 and 2008 figures based on visual inspection of the data. However, small differences are noted in the text.

Data is based on 27 responses as follows:

Management Research 2007:	15
MBA 2007:	4
Management Research 2008:	8

Note: Commitments on the part of the tutor meant that it was not possible to obtain feedback from him on the pedagogic outcome of the sessions.

3.4.1 Students' backgrounds

Previous degree studied:

Economics, Finance, Accounting, Business:	12	**44%**
Engineering:	8	**30%**
Maths, Computer Science & IT-related:	5	**19%**
Pure sciences:	3	**11%**
Other:	3	**11%**

Years since graduation – i.e. length of gap in studies attributable to work experience:

2 years or less:	2	**7%**
Between 2 and 5 years:	11	**41%**
More than 5 years but less than 10 years:	12	**44%**
10 years or more:	2	**7%**

Role in the organisation for which they worked:

Management:	7	**26%**
Consultancy:	7	**26%**
Analyst, incl. financial analyst:	3	**11%**
Other:	6	**22%**
Unclear or not stated:	4	**15%**

3.4.2 Motivation for, and expectations from, the experience of modelling

Categorisation of reasons for studying the elective module in Complex Systems (Management Research) / Managing Complexity (MBA):

Category	*No. of respondts*	*Examples:*
Specific interest in the domain:	7	"More exposure to non-deterministic system-modeling."
Possible relevance to work:	7	"I am very interested in the way organisations can get maximum value out of information, and felt this module would give me extra insights."
		"[I] hope that this will help me see the flaws with existing theories and will give me tools or at least a direction to think towards and manage more complex situations."
Relevance to studies:	2	"Potential to link aspects of the theoretical frameworks that underpin complex systems thinking to my MSc dissertation - Provide a theoretical contrast to the 'philosophy of science' elective."
Non-specific interest:	10	"Sounded interesting and a departure from other business courses!"
		"personal interest and to learn how to deal complex problems in life."
Other:	1	

Categorisation of ideas regarding use of the knowledge and skills gained from this module:

Category	*No. of respondts*	*Examples:*
Transferable to work	9	"I see the knowledge gathered here to be useful in critically evaluating strategies based on well known (but very restricted) theories."
		"Use at consulting work for agent base[d] simulation model."
		"to simulate patterns, potentially in stock markets."
		"To understand what can be done and to understand the results of others' results."
Development of personal skills	4	"work in a more structured way."
		"Using the theory from the course, I hope to understand and analyse complex problems in business and real life better."
		"seeing things from a higher level, not only seeing the tree, but also seeing the forest."
Help in studies (MSc, DPhil)	1	
No ideas as yet	13	

3.4.3 Previous experience of programming and modelling

Programming:

No experience:	12	**44%**
Some experience:	12	**44%**
Extensive experience:	3	**11%**

Languages used:

C++, Java:	8
Visual Basic and other forms of Basic:	6
C:	3
Fortran:	2
SQL:	2
Other:	5

Modelling:

No previous experience at all:	8	**30%**
I know something about modelling but have not done any:	7	**26%**
I have done some modelling:*	12	**44%**
I have extensive experience of modelling:	0	**0%**

* Also includes those who stated "Other" as they used that option to describe the modelling they had done.

Modelling tools used:

Microsoft Excel:	3
Domain-specific tools (e.g. Matlab):	3
Starlogo:	1
UML:	1
Other:	2

3.4.4 Feedback on use of the BehaviourComposer

Progress made in terms of the steps in the instructions on the worksheet (see Appendix):

Completed (17 steps):	4	**15%**
More than 75% (i.e. reached somewhere between steps 13 – 16):	7	**26%**
50% - 75% (i.e. reached somewhere between steps 9 – 12 inclusive):	7	**26%**
Less than 50% completed (i.e. reached step 8 or lower):	8	**30%**
Unclear, but got something working:	1	**4%**

Ratings of ease of learning to use, and ease of using, the BehaviourComposer:

Criterion	*1 (very easy)*	*2*	*3*	*4*	*5 (very difficult)*
How easy it was to learn to use the tool	5	10	17	3	2
	19%	**13%**	**26%**	**11%**	**7%**
How easy it was to determine what each microbehaviour does	3	12	6	5	1
	11%	**44%**	**22%**	**19%**	**4%**
How easy it was to find the microbehaviours that you needed	4	8	11	3	1
	15%	**30%**	**41%**	**11%**	**4%**

Criterion	*1 (very easy)*	*2*	*3*	*4*	*5 (very difficult)*
How easy it was to modify the microbehaviours to do what you wanted	9	9	7	2	0
	33%	**33%**	**26%**	**7%**	**0%**
Overall, how much you enjoyed using the tool	5	10	6	6	0
	19%	**37%**	**22%**	**22%**	**0%**

There is no obvious correlation between the ratings given here and students' previous programming or modelling experience.

Extent and nature of help received:

Source and extent of help	*Help with the modelling task*		*Help with using the BehaviourComposer*	
None: I worked it out for myself	16	**59%**	6	**22%**
I/we got help from another student (peer support)	9	**33%**	7	**26%**
Used the Answer sheet	3	**11%**	4	**15%**
A bit of expert help from members of the C2L project team	5	**19%**	17	**63%**
Quite a lot of expert help from members of the C2L project team	1	**4%**	2	**7%**

In answer to the question "Given adequate time and support, would you want to continue developing your Sugarscape model in the BehaviourComposer?":

22 students (81%) gave a positive response (very much/quite).
4 students (15%) had no opinion.
1 sudent (4%) gave a negative response (not very much/not at all).

Some of the positive respondents took a strategic view: viz. they would continue working on the model "if it would be useful to understanding the course more fully."

In rating their overall enjoyment of the session:

23 students (85%) gave a positive rating (very much/quite).
2 students (7%) had no opinion.
2 sudents (7%) gave a negative rating (not very much/not at all).

3.4.5 Feedback on pedagogic value of the exercise

Responses to the question *The BehaviourComposer is intended to make it easier for people without programming experience to build models. On the basis of your experience today, how far does it succeed in this aim?*

Positive comments:	18	**67%**
Ambivalent comments (i.e. cited strengths *and* shortcomings):	7	**26%**
Negative comments:	2	**7%**

Examples:

- "It is a highly successful tool and was a thoroughly enjoyable session. Very relevant to our complex systems module this term."
  Student was planning to continue to doctoral study; had responded generally favourably to the

usability questions, but had needed a little expert help with both task and tool. Had some programming, and extensive modelling, experience.

- "good, we can build a model without programming a line of code"
  From a student who had some programming and modelling experience, but give mixed responses to the usability questions: i.e. sees the potential of the BehaviourComposer(?).
- "Moderately well. Probably wouldn't have figured as much out without some programming experience."
  Student had previously worked as a trader in an investment bank; had some programming and modelling experience, but only made it to step 5 of the instructions.
- "difficult to say how it would be if we weren't simply follow[ing] a set of specific instructions."
  Comment re the restrictive nature of the exercise from a student who already had experience of both programming and modelling.
- "The program has a nice interface. It is easy to use when procedures are already developed but I believe it would not be so friendly when an user needs to create his own custom procedures."
  Student already had experience of both programming and modelling.
- "it was easy-to-use, but not intuitively easy to follow."
  Student already had experience of both programming and modelling, and had worked without any assistance; gave non-committal answers to the questions on usability. Could see the value of modelling in terms of personal development as well as relevance to work.
- "Not at all, very clunky and not user friendly."
  Verdict from a student who had a Chemistry degree and no experience of programming or modelling. He had received help from experts as well as peers and the answer sheet, and made it to step 8. He gave non-committal or negative responses to the usability questions and would only continue with his Sugarscape model "If it would be useful to understanding the course more fully." *Also commented that* "No value in working out the syntax of a new programming language nor searching the menus" *and* "2 minutes of expert help allows you to progress 45 minutes working on your own. My suggestion would be to have more mobile helpers, then you can concentrate on thinking about behaviours and not working out how the software works." *i.e. he seems to feel that the (usability of the) tool got in the way of the task – or maybe the low level of programming that was required was excessive (i.e. seems to be a strategic user).*

2008 cohort only: Impact of the session on students' understanding of the nature and purpose of modelling:

Question: As a result of today's session, to what extent has your understanding of the nature and purpose of modelling in management research changed?

Much better than before:	4
A bit better than before:	1
About the same as before:	2
A bit worse than before:	0
Much worse than before:	0
I can't really make a comparison	1

Additional comments:

- "The exercise is more on the software exercise level. Prior to this exercise, I've had some understanding of the nature & purpose." (i.e. benefit is technological)
- "It helped clarify the lectures." (i.e. benefit is conceptual)

4. THE "INFECTIOUS DISEASE" MODELLING SESSIONS

4.1 Background to the "Infectious Disease" sessions

In these sessions students modelled the spread of infectious diseases using a model based on the mathematical "SIR Model" developed by Kermack and McKendrick (1927). This model "computes the theoretical number of people infected with a contagious illness in a closed population over time. The name of this class of models derives from the fact that they involve coupled equations relating the number of susceptible people $S(t)$, number of people infected $I(t)$, and number of people who have recovered $R(t)$." (Weisstein, 2008).

The students were 3rd-year undergraduates in Biological Sciences taking an elective course in the Biology of Plant and Animal Disease, and the sessions took place in Week 3 of Michaelmas Term (i.e. October) 2007. The modelling activity was intended to link in with lectures on the modelling of infectious diseases, but the practical work was not formally examined.

4.2 Pedagogical aim of modelling the spread of infectious diseases

(This information was obtained during a meeting between the project evaluation specialist and the tutor approximately three weeks before the modelling sessions.)

Students normally gain experience in constructing and running the SIR model in two three-hour sessions at the end of their second year using R, a free tool for statistical computing (www.r-project.org). They are already familiar with the SIR model from lectures and textbooks, and the simulation in R builds arrays of numbers which they can then plot. For the purposes of the C2L evaluations, the key features of this exercise are a) the use of the differential equations to model the spread of disease analytically and b) the limitation of the model to the population as a whole.

Normally in the R sessions, students work in pairs (occasionally threes). The tutor estimates that 80% of them usually complete the tasks and acquire a "reasonable understanding" of the model. Another 5-10% already know something about modelling and computing, and find the task easy. The remainder, however, tend to struggle as they have no experience of programming. The tutor also reported that students normally enjoy working in R and feel that they are learning something useful. Even those who lack a strong mathematical background – and hence find it hard to think analytically and explain what they are doing in mathematical terms – appear to grasp the basic workings of the SIR model. Indeed, the tutor himself has come to modelling from a non-mathematical background and so has a great deal of empathy with the students. His approach is to help them i) understand the basics of why they are trying to create a model and what a model it can tell us, and ii) manipulate the model by writing small segments of code that enable him to ascertain their grasp of what is going on.

For the tutor, using the BehaviourComposer to model the spread of infectious diseases would have two key benefits: a) using the NetLogo programming language rather than differential equations would enable students to appreciate the probability of a disease outbreak expanding to epidemic levels (differential equations are deterministic in that, to quote the tutor, "there's always .001 of an infected person" and so an epidemic will always happen when the model is run); and b) the BehaviourComposer would enable students to model the behaviour of individuals within the population and to investigate the role of social networks in spreading disease, instead of just modelling the behaviour of the whole population. Students' lectures would have made the crude assumption that everyone has an equal chance of spreading a disease to someone else – which is not an accurate assumption for many diseases. To counter this, students would be encouraged to introduce networks of contacts into their

BehaviourComposer models: first fairly regular (i.e. where each individual in the population has the same number of networks) and then building up to a power-law distribution where some individuals have only one or two contacts, while others have a great many. This should show how a disease catches hold more quickly in certain areas.

4.3 Method

4.3.1 Research questions

The tutor defined his intended "take-home messages" for the BehaviourComposer session thus:

1. Learn to implement another way of modelling disease: simulation (BehaviourComposer) (i.e. as opposed to analytic, using R).
2. See one strength of such individual-based models in action: viz. the ability to introduce heterogeneity in order to make the model more realistic (in this case in the form of social networks along which the infection has to travel).
3. Learn how different types of social networks (with the same mean number of links) produce very different epidemics.
4. Ponder how other factors that will be important in predicting the spread of infectious disease could be thus included: e.g. spatial structure, chance and travel.

4.3.2 Data collection methods

Our primary method of collecting feedback was through an online survey of the students, to be completed at the end of the session. In addition, we wanted to collect as many models as we could for the project manager to investigate, but these were not analysed as part of the evaluation. However, we did have access to students' completed answer sheets.

Students signed a consent form giving the project team permission to use their work for research purposes.

The survey is included in the Appendix.

4.3.2 Format of sessions

The two evaluation sessions took place in a computer lab in the Department of Plant Sciences in October 2007 and lasted for two hours each; students attended one or the other according to their availability. The sessions formed part of the regular timetable for practical classes: i.e. unlike the earlier "Sugarscape" sessions they were not laid on especially for the C2L project.

Each session opened with an introduction to the activity from the tutor, with the remainder of the time taken up with the hands-on activities. To build their models, students followed step-by-step instructions on a worksheet prepared by their tutor in conjunction with Ken Kahn (see the Appendix). The practical was divided into two parts:

i) Rebuilding using the BehaviourComposer the SIR model that they had created the previous term in R, and considering the differences between the two approaches.

ii) Exploring the effects of introducing social networks into the model.

The worksheets included reflective questions about the learning task itself and a test of students' ability to identify other areas in biology in which the modelling of social networks might be relevant (sample answers to some of these questions are included in the worksheet reproduced in the Appendix). The tutor subsequently checked through the completed worksheets to make sure that students had done the work, but did not formally mark them.

Students worked in pairs or threesomes, in part to avoid overloading the departmental servers. The tutor was assisted by demonstrators (graduate research students), who went round the laboratory, looking over students' shoulders and checking on their grasp of the models. While the sessions were being planned, the tutor noted that he would need to train the demonstrators so that they would not simply give the answers straightaway, but would encourage the students to think along the right lines.

The sessions were preceded by a pilot session in which the demonstrators worked through the students' worksheet as a usability test of the worksheet, and also to see how long the activities were likely to take (in particular, the tutor wanted to be sure that students would get as far as modelling social networks).

4.4 Results

In total, 40 students attended the two sessions as follows:

Session A: 20 students - 7 pairs, 6 individuals; 1 tutor, 2 demonstrators
Session B: 20 students - 7 pairs, 2 threesomes individuals; 1 tutor, 2 demonstrators

The following is a summary of the data from 14 responses to the online survey from both sessions. Ten of these were individual responses, three were joint responses from two students, and one was a joint response from three students.

4.4.1 Motivation for studying the module "Biology of Plant and Animal Disease"

Categorisation of reasons:

Category	*No. of respondts*	*Examples:*
Specific interest in the domain:	7	"Interest in processes behind illness, recovery and disease prevention."
		"Love of animals and interest in the natural world following travel to places such as Kenya and the Falkland Islands"
Possible relevance to work:	7	"I find it to be the most interesting and challenging field, with cutting-edge research as well as being a way in which I could help the rest of the world."
		"A wish to understand the molecular mechanisms of disease and, how these interact with host defense mechanisms and how one can use this information to design treatments."
Non-specific interest:	3	

4.4.2 Previous relevant experience

Experience of programming:

No experience:	12	**86%**
Some experience:	1	**7%**
Extensive experience:	1	**7%**

Languages used were:

- PHP and Javascript (1)

- Visual Basic with Excel; also the Maple modelling tool (http://www.maplesoft.com/) (1) used respectively for chemical plant scheduling and modelling of disease progression and allele frequency in a population with HIV.

Experience of modelling:

No previous experience at all:	6	**43%**
I know something about modelling but have not done any:	4	**21%**
I have done some modelling:*	5	**36%**
I have extensive experience of modelling:	0	**0%**

Modelling tools used were Excel, Maple and R (interestingly, only five students admitted to having done any modelling before; they may have interpreted the question in terms of modelling other than the SIR model in R). The same user who said he had used Visual Basic in the previous question had also used Excel to model torque on robotic arms.

Highest qualification achieved in mathematics:

A2 (A level):	9
AS:	2
International Baccalaureat:	1
Scottish Higher:	1
GCSE:	4
AP (USA):	1

4.4.3 Feedback on usability aspects of the BehaviourComposer

All of the students completed both parts of the worksheet, but did not have time for the additional activities provided for those who finished early.

Ratings of ease of learning to use, and ease of using, the BehaviourComposer:

Criterion	*1 (very easy)*	*2*	*3*	*4*	*5 (very difficult)*
How easy it was to learn to use the tool	6	7	1	0	0
	43%	**50%**	**7%**	**0%**	**0%**
How easy it was to determine what each microbehaviour does	2	11	1	0	0
	14%	**79%**	**7%**	**0%**	**0%**
How easy it was to find the microbehaviours that you needed	5	3	5	0	1
	36%	**21%**	**36%**	**0%**	**7%**
How easy it was to modify the microbehaviours to do what you wanted	5	6	1	2	0
	36%	**43%**	**7%**	**14%**	**0%**
Overall, how much you enjoyed using the tool	4	5	5	0	0
	29%	**36%**	**36%**	**0%**	**0%**

As with the "Sugarscape" sessions, there is no obvious correlation between the ratings given here and students' previous programming or modelling experience. but the person with most prior experience of modelling (he had used Visual Basic and Maple) gave some of the lowest ratings for ease of use in finding and modifying microbehaviours.

Extent and nature of help received:

Source and extent of help	*Help with the modelling task*		*Help with using the BehaviourComposer*	
None: I worked it out for myself	5	**36%**	5	**36%**
I/we got help from another student (peer support)	2	**14%**	1	**7%**
A bit of expert help	8	**57%**	7	**50%**
Quite a lot of expert help	0	**0%**	1	**7%**

In answer to the question "Given adequate time and support, would you want to use the BehaviourComposer to build other models?":

8 responses (57%) were positive (very much/quite).
5 responses (36%) expressed no opinion.
1 response (7%) was negative (not very much/not at all).

Like the "Sugarscape" cohort, some students took a pragmatic line: "[I] would if I had to, but [I] don't have an interest in building models!" The one modelling "expert" commented that "Making it increasingly adaptable for those with some programing experience would make it more interesting."

In rating their overall enjoyment of the session:

11 responses (78%) were positive (very much/quite).
3 responses (21%) expressed no opinion.
0 responses (0%) were negative (not very much/not at all).

No-one made any substantial additional remarks in answering this question.

4.4.5 Feedback on pedagogic value of the exercise

Impact of the session on students' understanding of the nature and purpose of modelling:
Question: As a result of today's session, to what extent has your understanding of the nature and purpose of modelling in epidemiology changed?

Much better than before:	1
A bit better than before:	11
About the same as before:	2
A bit worse than before:	0
Much worse than before:	0
I can't really make a comparison	0

Additional comments:

- "[I] always knew modelling was useful for studying epidemiology. I thought modelling is unrealistic... but the model we used today made it a bit more realistic."
- "Didn't understand anything before, now understand relevence of social networks."
- "All [I] feel like I've learnt is the availability of a population or individual-based models" (but note that this was the intention of the exercise).

Comparison with R:

a) Responses to the question *You had already modelled the behaviour of populations analytically in the spread of disease using R. In terms of your learning, how valuable was it to construct the model in the BehaviourComposer and run it as a simulation as well as creating the analytical model? For example, did one way help you to understand the actual model better than the other?*

- BehaviourComposer superior to R in aiding understanding of the model itself: 8 responses

  e.g. "I think constructing the model in BehaviourComposer helped me to understand the actual model better than R."

- Easier to understand the analytical model (i.e. in R) but appreciation of the visual element of the BehaviourComposer: 2 responses from students with A level Maths

  e.g. "I think the analytical model helped my understand the mathematics behind the model better, although this model was easier to see the interactions between the members of the population because it had more of a visual element."

- Appreciation of the opportunity for comparison: 1 response

  "It was helpful to compare the different types of modelling, and to see the different ways in which they could be applied to the same problem. Knowing the way in which they work, and their strengths and weaknesses is very valuable."

- Usability of the BehaviourComposer compared favourably against R: 1 response

  "computing language distracted from the theory before"

- Usability of the BehaviourComposer compared unfavourably against R: 1 response
- Criticism of time delay between the two practical sessions: 2 responses

b) Responses to the question *You have now modelled the spread of infectious diseases both through the behaviour of populations and through the behaviour of individuals. In terms of your learning, how valuable was it to model the spread of infectious diseases in both these ways? Did you achieve any new insights or understandings through the individual-based model?*

- Individual-based made clear the stochastic (random) element in the spread of disease: 3 responses:

  "The individual-based model was useful for showing that individual behaviour may affect the spread of disease in a more random way."

- Individual-based model showed the role of social networks in the spread of disease: 2 responses
- Individual-based model showed the spread of disease of disease better: 2 responses
- Individual-based model was easier to understand than differential equations: 1 response

  "the previous practicals in R weren't easy to follow... not everyone understood differential equations, even by the end of the practical"

- Individual-based model compensated for the shortcomings of the R model: 1 response
- No specific insight or no comment: 5 responses

Suitability of the BehaviourComposer for non-programmers:
Responses to the question *The BehaviourComposer is intended to make it easier for people without programming experience to build models. On the basis of your experience today and your earlier practical using R, how far does it succeed in this aim?*

Positive comments:	14	**100%**
Ambivalent comments (i.e. cited strengths *and* shortcomings):	0	**0%**
Negative comments:	0	**0%**

Examples:

- "I think it succeeds well, I find the modelling aspect of disease quite challenging but today's exercise was quite clear"
- "Definitely: it was far easier to build a model than using R, and allowed more complex models to be constructed easily."

4.5 Analysis of answers on worksheets

The following is a rough-and-ready analysis by the project team of students' answers to the main questions posed on the worksheets. In total, 36 worksheets were received.

Difference between the model created in R and the first model created in the BehaviourComposer
Question: *What is the difference between these two models? (i.e. the difference between the analytical model created in R and the first individual-based model created by students in the BehaviourComposer, which approximated to that analytic model)*

Expected answer: *In R we make a numerical approximation of an analytical model; chance only in rounding function.*

Categorisation of answers given:

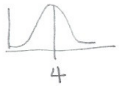
Category	*No. of answers*
Answers related to the nature of the model:	
▪ Approximations to the correct answer: i.e. mention of the stochastic rounding function in R and/or BC better at dealing with the element of chance because it lies at the level of the individual(?) and/or R model more deterministic:	18
▪ Repetition of the individual-based vs population-based nature of the two models:	13
Answers related to observations of phenomena in the model:	2
Answers related to properties or functionality of the software: e.g. the way in which parameters, categories etc. can be varied in the BehaviourComposer	11
Answers related to software usability: e.g. comparative user-friendliness of the BehaviourComposer	3
No response:	1
Total:	**48**

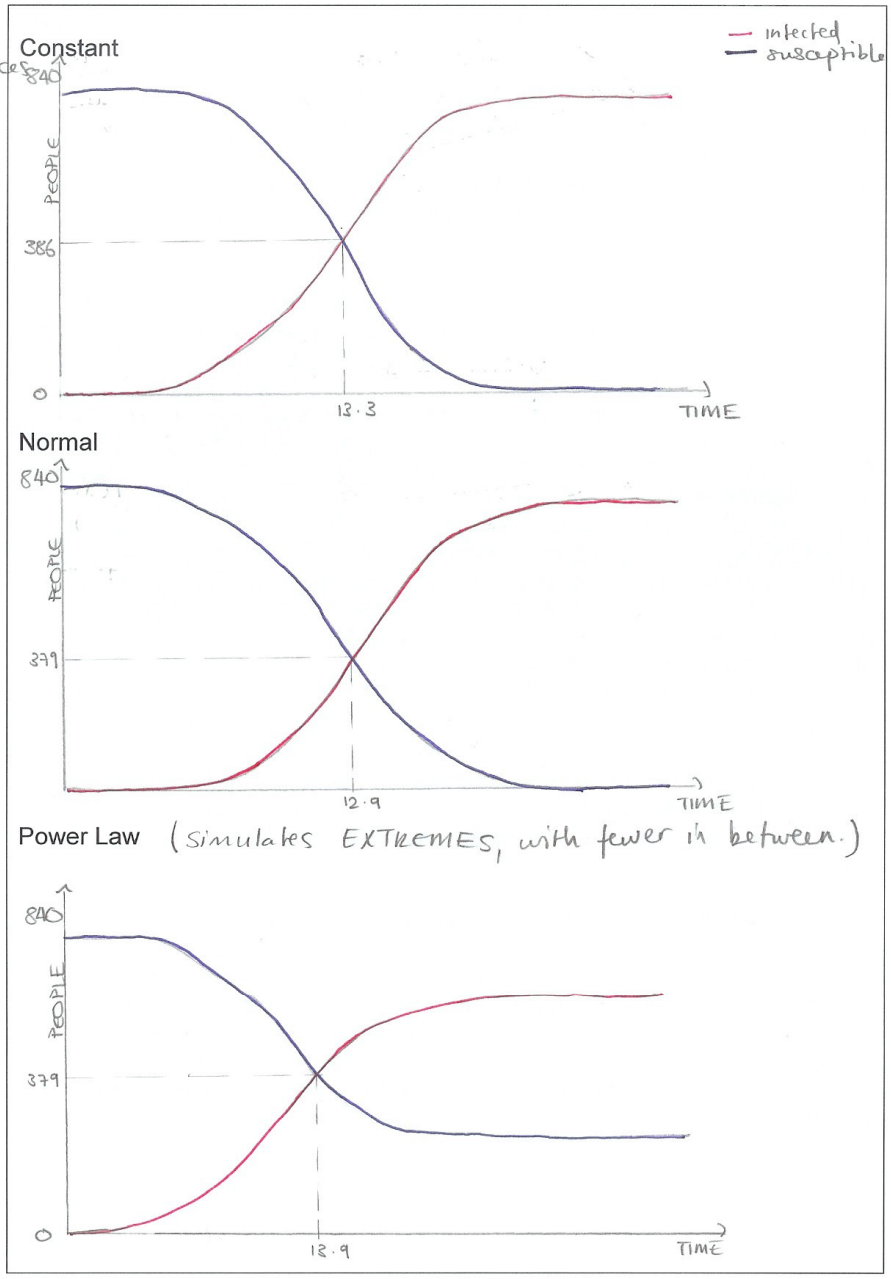
That is, according to our analysis roughly 50% of the students gave the correct answer (note that some gave more than one answer). However, for a different perspective see the tutor's view reported on page 21.

An example of the three graphs plotted as instructed on page 6 of the worksheet:
(For a discussion of these graphs, see page 22.)

3. **INITIALISE-SOCIAL-NETWORK-POWER-LAW-DISTRIBUTION-SYMMETRIC**. Here we use a power distribution to determine how many acquaintances an individual has. Draw the three plots below and show values for critical parts of the graphs.

All have 4 aquaintances

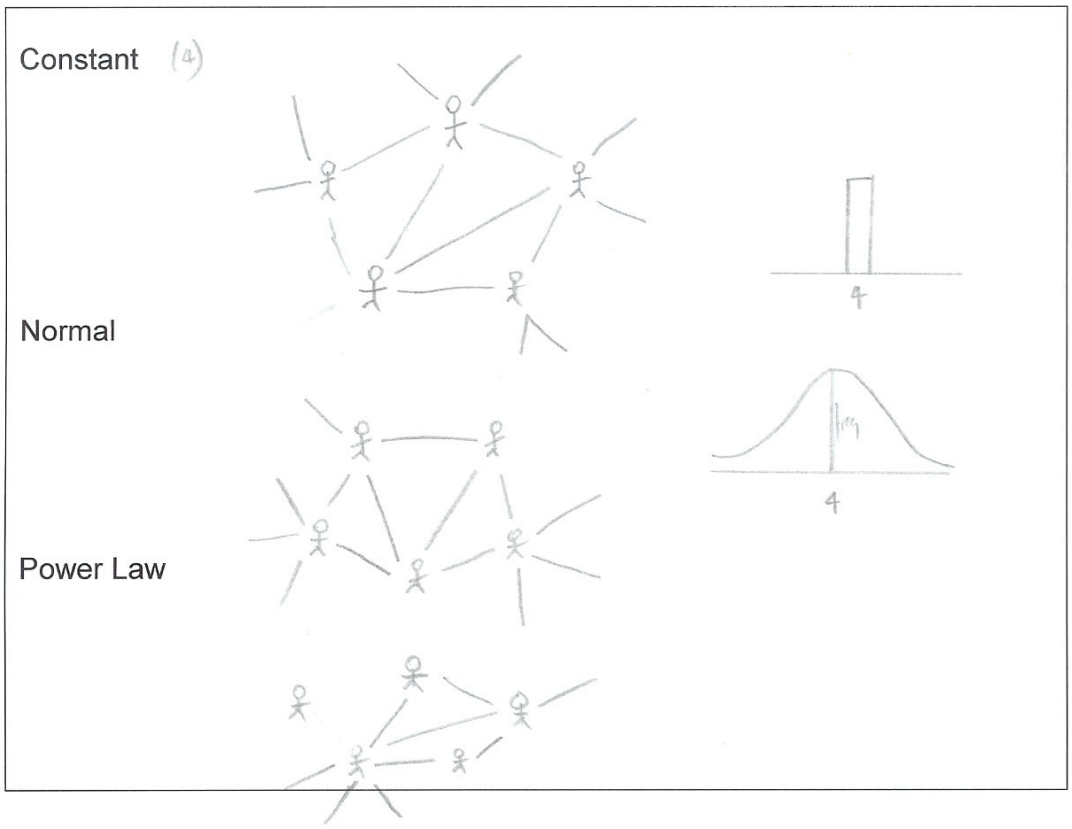




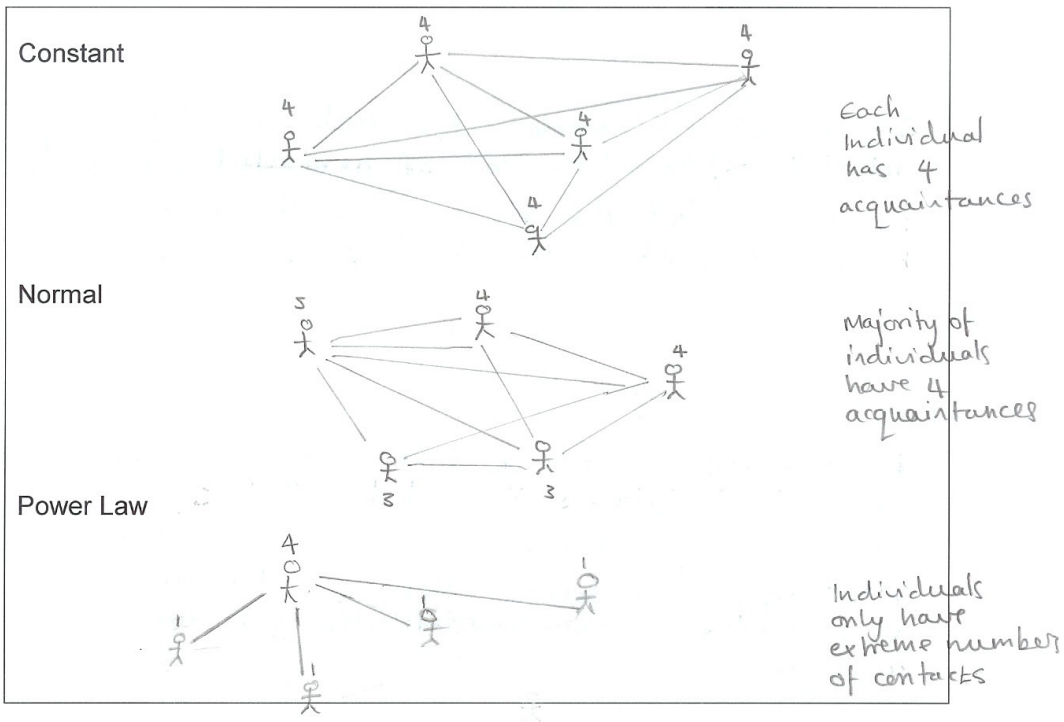
6

Examples of the three types of social networks – constant, normal and power law – drawn as instructed on page 7 of the worksheet:

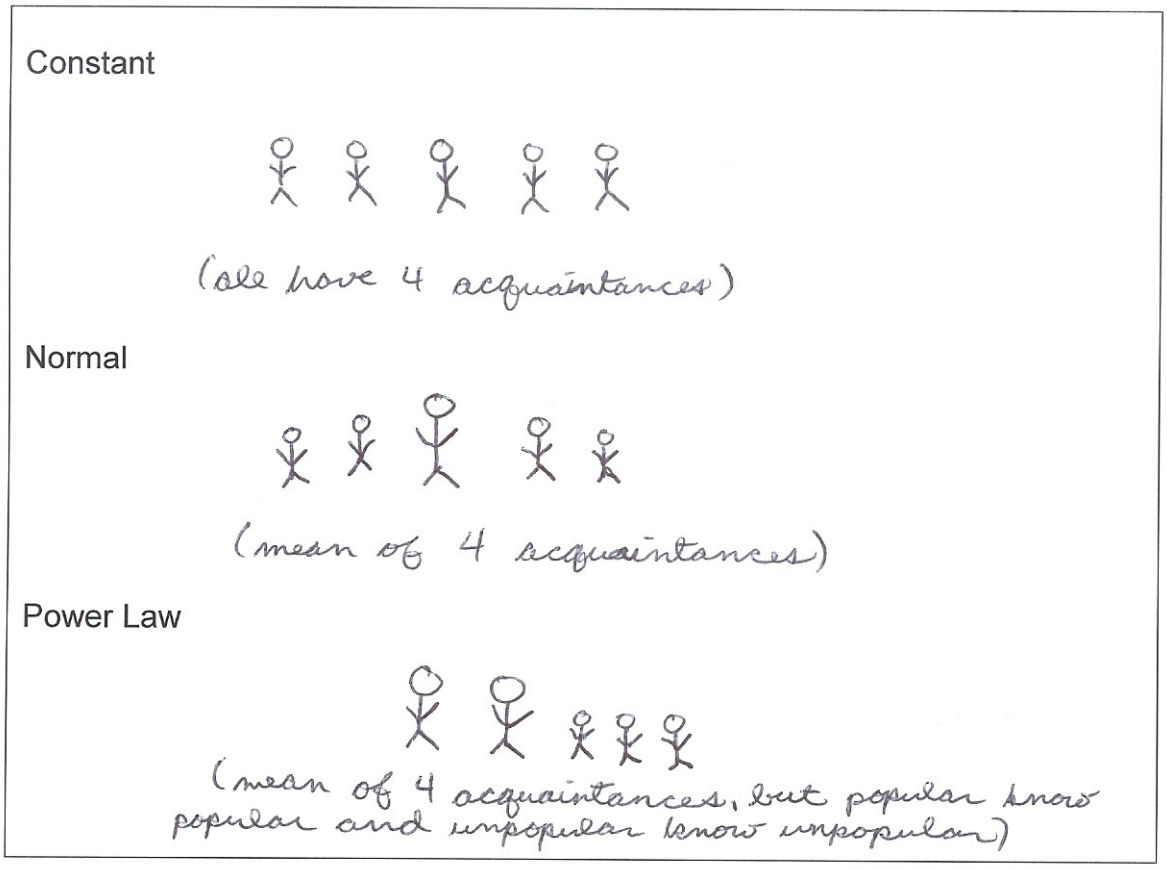
a) Student has drawn a similar representation of the networks to the model answer in the worksheet:



b) Student has drawn the networks explicitly, showing links between individuals, but differently from the model answer in the worksheet:



c) Student has represented the size of each person's network by drawing individuals of differing sizes:



Modelling social networks in R:
Question: *How could one have modelled this inclusion of social networks using the population model in R that we created in the earlier practicals?*

Expected answer: *More compartments with different classes of "Infecteds."*

20 students gave an answer approximating to the expected one, 13 gave incorrect answers, 3 said that it was not possible to model social networks in R, 1 answer was unclear and 1 person did not give an answer (total = 38 answers).

Other factors in disease spread that could be modelled this way:
Question: *Apart from representing social networks, what other important factors in the spread of a disease could be represented by this new parameter?*

Expected answer: *Spatially explicit models to include population clumping (cities, farms, hospitals, schools etc.) and travel routes (e.g. air links and SARS).*

13 students gave an answer approximating to the expected one; 10 suggested that different transmission methods could be represented in this way; and the remainder were not easily classified (total = 54 answers).

Strengths and weakness of individual-based models:
Question: *In general, what do you think would be the strengths and weaknesses of these individual-based models compared to analytical ones?*

Expected answers for strengths:
1. Can incorporate complex heterogeneity more easily (although perhaps only to a certain level)

2. Easier to estimate important role of probability in disease spread, e.g. does the epidemic take off or not. This can be done analytically with probability functions, but is difficult.

21 students gave an answer approximating to answer 1; 11 gave an answer approximating to answer 2. Other frequently cited "strengths" were: more realistic models (12), the ability to model social networks (9) and the ability to study the behaviour of individuals (8). Some other responses appeared to miss the mark in that, for example, they related solely to the "infectious diseases" model or cited properties of the software used to create the model (functionality, usability). (Total = 80 answers)

Expected answers for weaknesses:

1. *Provided not too complex, analytic models can be easier to interpret and investigate.*
2. *More computationally demanding (although this has improved recently).*

6 students gave an answer approximating to answer 1; 10 gave an answer approximating to answer 2. 6 students spoke in terms of individual-based models being more demanding on the user's time and skills, and 4 commented that it was harder to make predictions. Again, a few students cited the properties of the software as a weakness. (Total = 53 answers)

4.6 Tutor's reflections on the sessions

The following are the key points emerging from a meeting between the project evaluation specialist and the tutor, which took place approximately three weeks after the "Infectious Diseases" sessions (the notes were taken from an audio recording of the meeting and have been organised under headings for the purpose of analysis).

Lack of assessment and its possible influence on students and tutor
As already noted, the work done by students during their practical classes is not formally assessed (all that is required is that they do the practical "satisfactorily"), which might suggest that they do not engage with it as deeply as with work that they know will count towards their final examinations. The tutor expressed the view that it is unfair to divide students' activities into those that are directed towards summative assessment and those that are directed towards general learning: rather, he felt that the two aims should be integrated (i.e. both should be served by the same activities).

This lack of assessment had its greatest impact, though, on the tutor: in particular on his approach to designing the session. As he admitted, if he had to mark the worksheets he would spend longer planning the session and designing the questions such that they could be marked – which would be both time-consuming and "hard."

Achievement of the learning outcomes
Since the sessions were not formally assessed, it was possible to gain only an impression of the extent to which the learning outcomes were achieved.

Appreciating the theoretical difference between the analytical model created in R and the first individual-based model:
Reviewing students' answers to the question "What is the difference between these two models?" (see page 17), the tutor felt that many students failed to grasp the difference between the two models: i.e. that the analytical model is deterministic, while the individual-based model introduced the notion of probability in the spread of an infection. Even though many responses included the key words "stochasticity" and "deterministic," the tutor commented that "I'm not convinced that the student could have explained that to me" (something that we failed to appreciate in our own analysis in section 4.5).

The tutor attributed students' failure in this respect to two main factors. First, he identified shortcomings in his learning design (our phrase): it would have been better a) to get the students to understand how the model is built up from individual interactions (e.g. by examining the properties of the individual agents in the BehaviourComposer), and b) to place the comparative question at the end of the worksheet. Second, inherent properties in the R tool introduced a misleading stochastic element into the analytical model, whereas the model is actually a deterministic one. R is not the ideal tool for this purpose (a more suitable software takes a lot of time to install on the system and so the tutor does not use it), and so students had to *approximate* the differential equations underlying the model. The rounding function within R is stochastic in nature, which meant that successive runs of the model (with the same data) produced differing results. Thus, although R was a useful tool for introducing students to modelling per se, it was unsuitable for helping them to appreciate the theoretical distinctions among different types of model. (Software for implementing models based on differential equations exists, but unlike R is not available *gratis*.)

Appreciating the role of social networks:
Students used the BehaviourComposer to model the impact of three forms of distribution of social network: constant, normal and power law. Again, however, the exercise was unsatisfactory, this time on account of the way the model was implemented within the BehaviourComposer. The contact rate between an individual and the others in their social network had been implemented as a constant value, and as a result there was little difference in the rate at which the disease spread in the power-law distribution and the normal distribution (shown by the similar cross-over points in the graphs on page 18). This contrasts with the "intuitive" outcome, which is that a power-law distribution of social networks would accelerate the spread of the disease (i.e. one would intuitively expect the contact rate to be related to the number of acquaintances that an individual has). This is not an error in the model itself; rather, it is a genuine question of how one models real-world phenomena – a concept that was too difficult for the students to grasp at this stage. Thus, the tutor felt that, for students to appreciate the differences among the three forms of social network, he would need to design another exercise which would result instead in an outcome that matched their intuitive expectation.

Approach to learning design
The tutor did not feel that the experience had had an impact on his overall teaching approach, as he had simply followed the conventional format for practical sessions. Moreover, since Ken Kahn had done much of the planning, he had actually spent less time than usual designing the session.

The tutor also described his approach to using technology in his teaching as one of "risk minimisation:" "you always go for things you know will work." His reason for continuing to use the BehaviourComposer in future sessions was confidence in Ken Kahn.

Overall impressions of the session
Summarising, the tutor felt that the sessions went "splendidly well," and that they were interesting and stimulating for the students. He was satisfied with the two-part structure (i.e. replicating the model originally run in R and then modelling the impact of social networks). He had identified a number of issues in relation to the design of the session, the ontologies of the models themselves, and the tools used to implement the models, and could see what changes he would make when running the sessions in the future.

5. CONCLUDING REFLECTIONS

Pedagogic value of the BehaviourComposer

The underlying aim of the C2L project was to build a tool that enabled students to create models of complex phenomena in the social and life sciences with minimal programming knowledge, and this is reflected in the motivation of the "Sugarscape" tutor in particular. However, it is difficult to assess the extent to which this aim was successful, given that a) students' interactions with the BehaviourComposer were heavily directed (through the worksheets) so they did not have opportunities to experiment freely with it, and b) the activities were not formally assessed. Moreover, their own feedback is mixed: some found working with the tool relatively straightforward despite their lack of previous programming experience, while others who had done programming before felt that they would not have progressed without that existing knowledge.

However, although the learning outcomes may have been in doubt, the "Infectious Disease" sessions indicated important implications *vis-à-vis* students' meta-theoretical understanding, which can be considerably affected both by the properties of the modelling tool itself and/or the way in which the ontology of the world being represented is implemented in the model. The choice of R – a freely available tool – over a dedicated tool for modelling differential equations led to a blurring of students' understanding of the stochastic element in the spread of infectious diseases, while the inclusion of a constant contact rate in the model supported by the BehaviourComposer clouded their grasp of the effects of different forms of social networks on that spread. An important "learning design" issue, then, is to furnish activities that facilitate students' understanding of the phenomena being modelled and, hence, enable them to make predictions and solve problems regarding those phenomena, while protecting the students from complex, but essential, meta-theoretical issues until they are ready to engage with them.

Challenges to evaluating innovative technologies in an HE environment

Our initial research questions were ambitious and relied upon extended use by interested parties. However, although Ken Kahn identified, and met with, a number of interested academics, we were obliged to curtail those ambitions in view of the limited penetration of modelling at the undergraduate level, the early loss of key supporters of the project and the concentrated nature of the university curriculum which makes it difficult, if not impossible, to replace pre-specified components of the course with experimental sessions of this kind – problems that are almost certainly not unique to Oxford University. Inserting optional sessions did not really work in the 2007 "Sugarscape" evaluations, particularly where the evaluation session preceded the class in which the students were to learn about the Sugarscape model in detail.

Greater success, in terms of meaningful data, was obtained from the "Infectious Diseases" sessions, where the sessions were more fully integrated into the curriculum. The shortcoming here lay in the non-assessed nature of the task, which meant that learning outcomes could not be measured in an objective way. However, though the pre- and post-session interviews with the tutor yielded valuable insights into students' misconceptions and the challenges associated with representing the world in cut-down form (as discussed above).

Contribution of the C2L evaluation to our shared understanding of D4L

The community's understanding of D4L is continually evolving, from early definitions such as Dalziel (2003) and JISC (2004) to a recent conception that foregrounds the "design-like" skills needed by teachers in planning for e-learning: for example, the representation of ideas in a

more explicit way, the re-interpretation of the curriculum in new contexts, and continuous evaluation (Beetham, 2008).

C2L was rooted in Ken Kahn's longstanding interest in learning through modelling, programming and computer animation. However, within the D4L programme it was conceived primarily as a technical development project (demonstrated also in the embedding of the BehaviourComposer as a tool within LAMS) and lacked the emphasis laid on the pedagogic aspects of learning design by projects such as DeSILA and eLIDA CAMEL, with which the author of this report was also involved. This is not a criticism of C2L – which indeed accomplished much – but it explains why the project made a smaller contribution than others to our collective understanding of D4L. True, the BehaviourComposer made it possible for both tutors to enhance their students' learning experience, but this does not require an explicit D4L framework to achieve, and there is certainly no evidence of an alteration in perspective in the post-session reflections of the second tutor. Both he and the first tutor implemented the BehaviourComposer within the context of their existing pedagogies.

Future development of the BehaviourComposer

Since the official end of the C2L project in December 2007 the BehaviourComposer has been used again for modelling Sugarscape (covered in this report). A successor project funded by Eduserv, Modelling4All (http://modelling4all.wikidot.com/), has been under way since August 2007. The new project has a less pedagogical focus, in that it aims to enable and support a community of model-builders comprising both students and seasoned researchers. Both the software architecture and the interface of the BehaviourComposer have been extensively revised, and a number of usability issues raised during the C2L project have been addressed.

From an evaluation perspective, the Modelling4All project poses different challenges (how can one defined and evaluate the "success" of such a community?) from evaluating a modelling tool within a formal pedagogic context. Yet the evaluation of the BehaviourComposer has shown that much work still needs to be done to design and carry out effective evaluations of modelling tools within formal learning contexts in order to yield the kinds of findings (and findings that are not just centred on the measurement of learning outcomes) that will persuade educational institutions to appreciate the pedagogic value of modelling and implement it as a teaching and learning technique on a broader front – and, hence, to furnish online communities such as Modelling4All with the members on which they will rely in order to thrive and demonstrate their own value.

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APPENDIX

This appendix reproduces a number of the documents used in the C2L evaluations:

Worksheet for the "Sugarscape" model

Online survey for the "Sugarscape" model
(2008 version: question 16 was omitted from the 2007 session.)

Worksheet for the "Spread of Infectious Diseases" model

Online survey for the "Spread of Infectious Diseases" model

A Guide to Reconstructing Sugarscape

in the BehaviourComposer

Sugarscape is an artificial world with life, death, wealth, sex, culture, trade, and disease described in *Growing Artificial Societies* by Joshua M. Epstein and Robert Axtell, Brookings Institute Press, The MIT Press, 1996. Here we focus upon life, death, and wealth from chapter 2.

By Ken Kahn, kenneth.kahn@oucs.ox.ac.uk
April 18, 2007

Step -1. Installation of the BehaviourComposer

Download http://tinyurl.com/35d5uk and unzip it wherever you like. Try double clicking on the **run_introduction** icon**.** If that doesn't work ask for help.

Step 0. Logging in to the Introductory Lesson

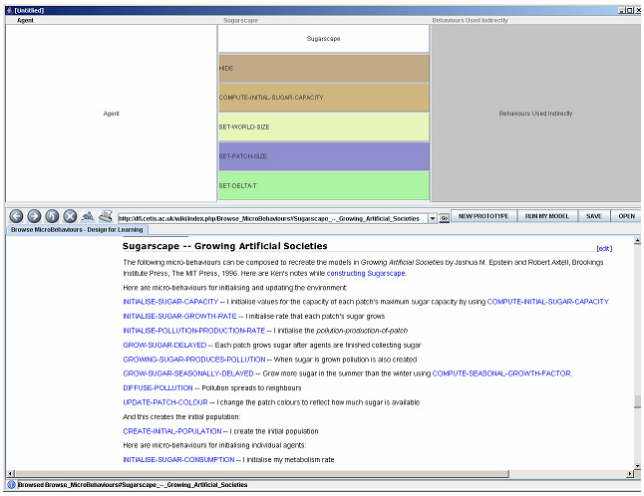
Your user name and password is MBA39. Ask for help if it doesn't work. Click on the "Introduction to the Behaviour Composer version 3" link and wait for the further instructions.

Building Sugarscape

Restart the BehaviourComposer and double click on the **run_empty_sugarscape** icon.

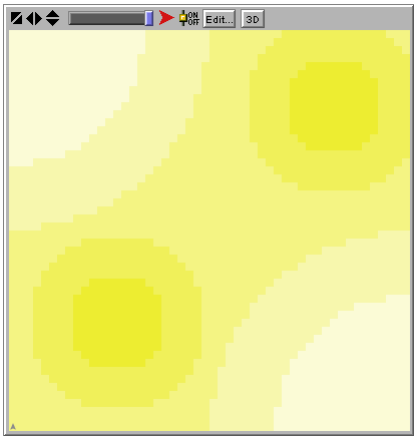
Step 1. Building the environment

You should be starting with the "empty" Sugarscape model that looks like this:



The environment needs to be initialised and given the behaviour of producing sugar. To do this you'll need to add **INITIALISE-SUGAR-CAPACITY** so that each patch of the Sugarscape has a maximum sugar capacity, **INITIALISE-SUGAR-GROWTH-RATE** to set the rate in which sugar grows, **GROW-SUGAR-DELAYED** to grow the sugar, and **UPDATE-PATCH-COLOUR** so the patches are coloured to reflect the amount of sugar accumulated. Clicking on the *RUN MY*

MODEL button and then NetLogo's *go* button should produce the following after a few seconds:



Step 2. Creating an Agent

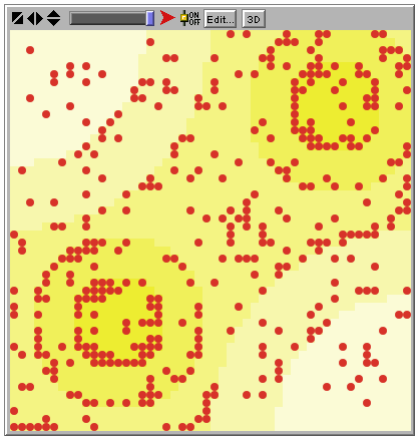
Next we will create an agent to live in the Sugarscape. (Actually it is already there as a gray triangle in the lower left corner, here you will give it an appearance and initial attributes. Add behaviours to the Agent to initialise it, to give it an initial random position, and the shape and colour that you prefer. Search the *Appearance* and *Movement* sections.

Step 3. Make the Agent Move

Add a behaviour from the *Sugarscape* section to make the agent move to the nearest patch with the most sugar that it can see. Note that you also need to add a behaviour that defines the agent's preference for patches with more sugar. When you run the model, you may see the agent move a little bit before it stops. You can produce different "trials'' by clicking on the *setup* button followed by the *go* button. Think about why it doesn't keep moving or sometimes doesn't move at all.

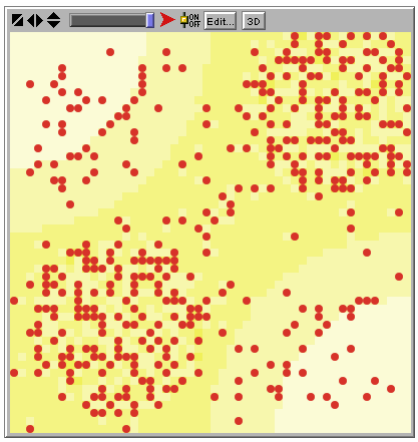
Step 4. Creating a Population

Add a behaviour from the *Sugarscape* section to initialise the population of 400 agents. Running the model should show the agents stopping with a pattern similar to this:



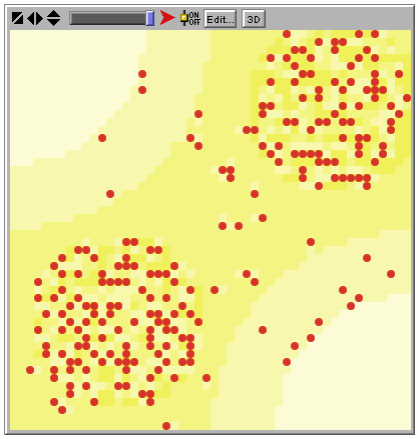
Step 5. Collecting and Consuming Sugar

Give the agents the behaviours of collecting and consuming sugar. Why do they keep moving the way they do? A typical snapshot should look like:



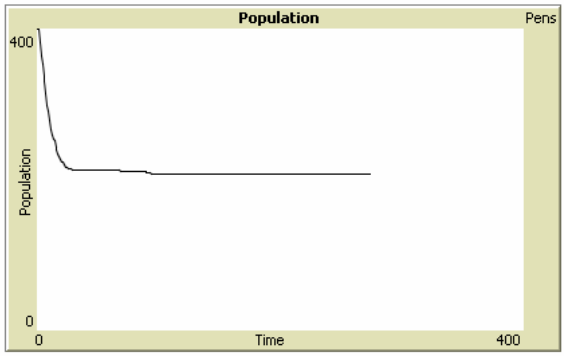
Step 6. Starving Agents

When agents have no sugar to consume they should die. Use a Sugarscape section micro-behaviour. After a while the model will look like the following. Think about why the agents on the lightest shade of yellow don't move.



Step 7. Graphing the Population

Add a graph of the total population versus elapsed time. The graph should look like the following. Think about why it drops and then levels off.



Step 8. Add a Histogram of Accumulated Sugar

Add a histogram of the distribution of wealth (i.e. sugar) of the population.

Step 9. Add a Lorenz Curve and a Monitor for the Gini Coefficient

These are additional tools for observing the distribution of wealth in the Sugarscape. See page 36 of *Growing Artificial Societies.*

Step 10. Add Monitors for Vision Level, Sugar Metabolism, and Time

Notice how the vision level and sugar metabolism change as the model runs.

Step 11. Replacing Dying Agents

Add a behaviour so new agents are created when an agent dies. See how this affects the dynamics of the mean vision level, the mean sugar metabolism, and the wealth distribution. Since the Population Graph is now useless remove or inactive it. Change the total population to 250 by editing the behaviour for creating the initial population.

Step 12. Limited Lifetimes

Give the agents behaviours so they die when they reach their lifespan. See how this affects the dynamics of the mean vision level, the mean sugar metabolism, and the wealth distribution. Note that the way aging is modelled this will begin to have an effect after 60 time steps.

Step 13. Production Causes Pollution

Add behaviours so that sugar production causes pollution. Change the way agents move so they tend to avoid polluted areas. Observe the modified dynamics. Note that the production of pollution doesn't begin before 50 time steps.

Step 14. Consumption Causes Pollution

Add behaviours so that sugar consumption causes pollution. This also begins after 50 time steps.

Step 15. Diffusing Pollution

Add the behaviour so that after 100 time steps pollution starts to diffuse to neighbouring sites.

Step 16. Save your model and email it to us.

Please send email to kenneth.kahn@oucs.ox.ac.uk attaching your model (or models) and the log file (or files) you'll find in the logs subfolder of the BehaviourComposer folder. And please fill out the questionnaire at http://tinyurl.com/2tpms2

Step 17. If you have time, explore the space of possible Sugarscape models.

For example, replace the behaviour for growing sugar with one that has differential seasonal growth rates. Or replace the initial distribution of the population with one where everyone starts in the Southwest corner. Or explore the parameter space. NetLogo has a tool for automating the exploration of the parameter space. Click on *Tools* and *BehaviorSpace* to try it out.

And please send us those models too.

Constructing2Learn: Feedback on Sugarscape Session May 2008

About this Survey

The modelling session that you have just done is part of a research project, and we would like to hear about your experiences and opinions. Questions with a * next to them are ones that you have to answer.

Although we ask for your name, we will treat your answers in strict confidentiality. We will, however, give a summary of the findings to Felix.

When you have finished, click The End after the last question to save your answers and exit. (Don't press the Cancel button at the top of your screen or close your Web browser; otherwise, you'll lose everything that you have written.) Note that once you have clicked "The End", you may not be able to go back and change your answers.

Thank you for your help.

GENERAL INFORMATION ABOUT YOU:

* 1. We will not identify you by name in any published work.

* 2. Your email address.
This is so that we can get back to you if we would like more information about some of your responses. If you don't wish us to contact you at all, please type NO in this box.

* 3. What subject(s) did you study in your previous degree(s)?
E.g. Maths, Economics, English

* 4. How many years is it since you completed your last degree?
(Count back from the beginning of this course: i.e. October 2007)

- ◯ 2 years or less
- ◯ Between 2 and 5 years
- ◯ More than 5 but less than 10 years
- ◯ 10 years or more

5. If you were working immediately before this course please tell us briefly:
- In what sort of organisation did you work? (e.g. small company, large company, university, government department)
- What was its line of business? (e.g. accountancy, management consultancy)
- What was your job title?

* 6. Why did you choose this elective module?

Constructing2Learn: Feedback on Sugarscape Session May 2008

* 7. At this stage, how do you imagine using the knowledge and skills gained from this module after you have completed the MBA?

* 8. Have you had any previous experience of computer programming?

- ◯ No experience at all
- ◯ Some experience
- ◯ Extensive experience

9. If you have had some or extensive programming experience, please tell us:
- The main language(s) you used
- The domain (e.g. business software, scientific)

* 10. Have you had any previous experience of modelling?

- ◯ No previous experience at all
- ◯ I know something about modelling but have not done any
- ◯ I have done some modelling
- ◯ I have extensive experience of modelling
- ◯ Other (please specify)

11. If you have had some or extensive modelling experience, please tell us what languages you used and what sort of models you created:

ABOUT YOUR EXPERIENCE CREATING A SUGARSCAPE MODEL TODAY:

12. Please paste the "session URL" from the bottom of the Behaviour Composer web page where you created your model. This will enable us to connect your model with this questionnaire. It will look like this:
http://modelling4all.nsms.ox.ac.uk/Model/?session=0jKpZeWknjpVuOxfJ_B849

* 13. Did you work...

- ◯ On a computer by yourself?
- ◯ Sharing a computer with another student?

14. If you worked with someone else, what is their name?
This is so that we can compare your responses with each other.

Constructing2Learn: Feedback on Sugarscape Session May 2008

* 15. How far did you get creating your model?
i.e. Which step did you get to? If you finished all the steps, did you carry on experimenting?

16. As a result of today's session, to what extent has your understanding of the nature and purpose of modelling in management research changed?

- ◯ Much better than before
- ◯ A bit better than before
- ◯ About the same as before
- ◯ A bit worse than before
- ◯ Much worse than before
- ◯ I can't really make a comparison

Feel free to clarify your answer here:

* 17. Thinking about your use of the BehaviourComposer tool, please rate the following aspects:

	1 (Very easy)	2	3	4	5 (Very difficult)	Not applicable
How easy it was to LEARN to use the tool	◯	◯	◯	◯	◯	◯
How easy it was to DETERMINE what each microbehaviour does	◯	◯	◯	◯	◯	◯
How easy it was to FIND the microbehaviours that you needed	◯	◯	◯	◯	◯	◯
How easy it was to MODIFY the microbehaviours to do what you wanted	◯	◯	◯	◯	◯	◯
Overall, how much you ENJOYED using the tool	◯	◯	◯	◯	◯	◯

* 18. How much help did you need? Tick as many boxes as apply (Expert help = Ken or Howard)

	None: I worked it out for myself (if in a pair: we worked it out for ourselves)	I/we got help from another student (peer support)	Used the Answer sheet	A bit of expert help	Quite a lot of expert help
Help with understanding the task (what we were supposed to do)	☐	☐	☐	☐	☐
Help with using the BehaviourComposer tool	☐	☐	☐	☐	☐

19. Feel free to make any additional comments here about the amount of help that you needed:

* 20. The BehaviourComposer is intended to make it easier for people without programming experience to build models. On the basis of your experience today, how far does it succeed in this aim?

* 21. Given adequate time and support, would you want to continue developing your Sugarscape model in the BehaviourComposer?

- ◯ Yes, very much
- ◯ I'd quite like to
- ◯ No particular opinion
- ◯ Not very much
- ◯ Not at all

22. Feel free to clarify your answer here:

* 23. Overall, how much have you enjoyed today's session?

- ◯ Very much
- ◯ Quite enjoyed it
- ◯ No particular opinion
- ◯ Not very much
- ◯ Not at all

24. Feel free to clarify your answer here:

25. Is there anything else that you would like to tell us about your experiences today?

Name:

BD 3.5 Practical: Individual Based Models

Here we will model a disease by building interactions of individuals rather than modelling mathematically with variables that represent entire populations.

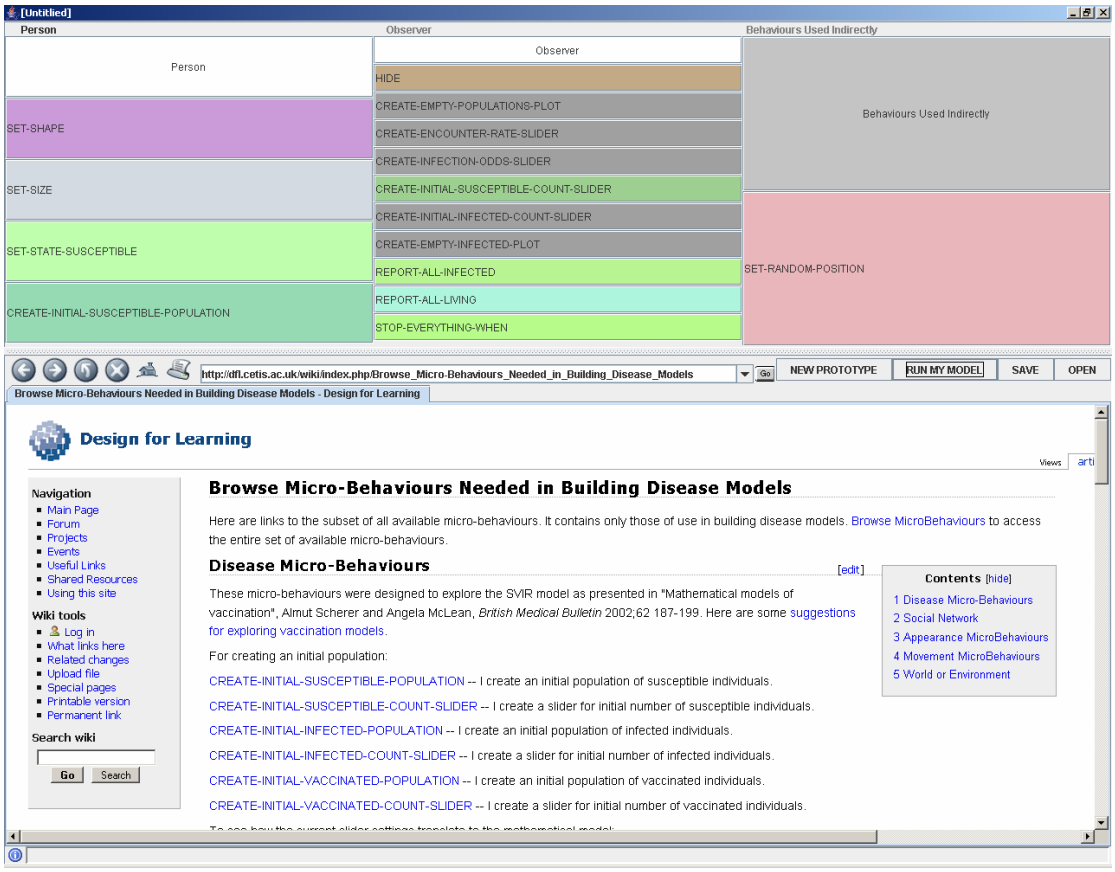
After accomplishing the first five steps you'll have a model equivalent to the SIR model you have already built in R. But the methodology here is very different: the program describes the behaviours of individuals and the behaviour of the population emerges. The SIR model you built in R describes populations. After building the equivalent model you'll explore the influence of spatial and social heterogeneity on the spread of diseases. This would be very hard to model analytically with equations that model populations. Put your name above and hand in at the end of the practical.

Step 1. Start the program.

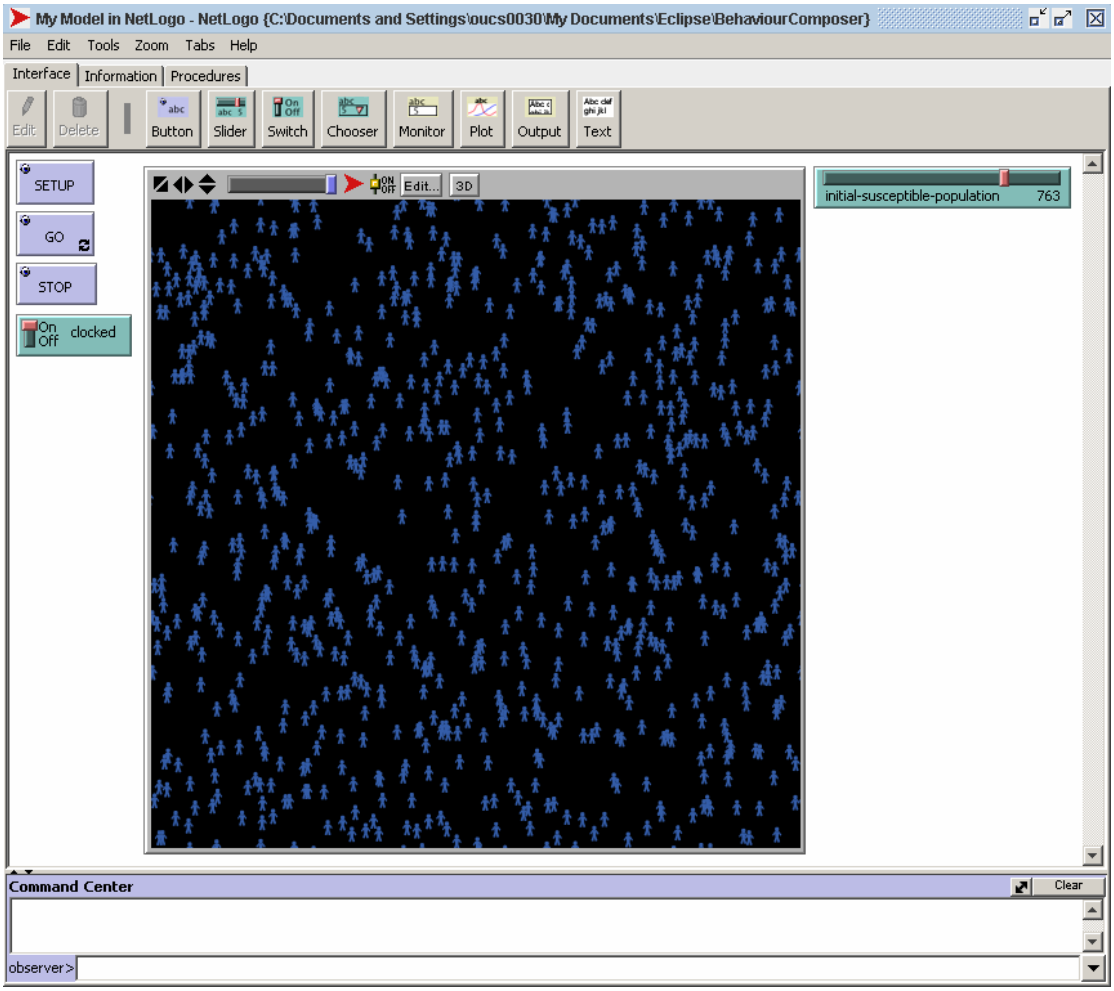
Copy BehaviourComposer from the TeachingResources Folder to your My Documents folder. Click on file called run_empty_disease_model.

Step 2. Explore the initial model

You should be starting with a model that includes susceptible and infected people. Adjust so that it fits the screen fully. It looks like this:



Click on the *RUN MY MODEL* button and then NetLogo, a different modelling tool is launched with the model constructed so far. Click on NetLogo's *setup* button to initialise the model. It should look like this:



Try changing the slider labelled **initial-susceptible-population** and then click on the *SETUP* button to see its effect. To move the slider by small amounts, set it slider near the desired value and click the mouse to the left or right to move it by one unit.

Pressing the *GO* button does nothing since we have yet to introduce infected individuals or any other behaviours.

Step 3. Create some infected individuals

Navigate to the web page on the lower half of your screen. Find the **CREATE-INITIAL-INFECTED-POPULATION** micro-behaviour and open it. Click on the button labelled "Add this code to Person" to create an initial population of infected individuals – it adds this to the upper part of the screen (if the button reads 'Add this code to Observer', click on the Person menu at the top left of the screen). On the right side of the upper window you'll see a micro-behaviour named "**POSSIBLY-RECOVER**" and we do not wish to use this, so right click on it and select 'Inactivate" from the menu (it becomes grey). Then

right click on the micro-behaviour labelled **"CREATE-INITIAL-INFECTED-COUNT-SLIDER"** and select "Activate". Run your model and you'll see an infected individual displayed in red when you click on *SETUP*.

Step 4. Spread the infection

The simplest way to model encounters is where an individual randomly encounters another and probabilistically infects that person. This is implemented by the **RANDOM-ENCOUNTER** micro-behaviour. Browse for it and add it to Person. It needs the **CREATE-ENCOUNTER-RATE-SLIDER** and **CREATE-INFECTION-ODDS-SLIDER** micro-behaviours, which are already at the top middle of your screen, so right click on them and activate them.

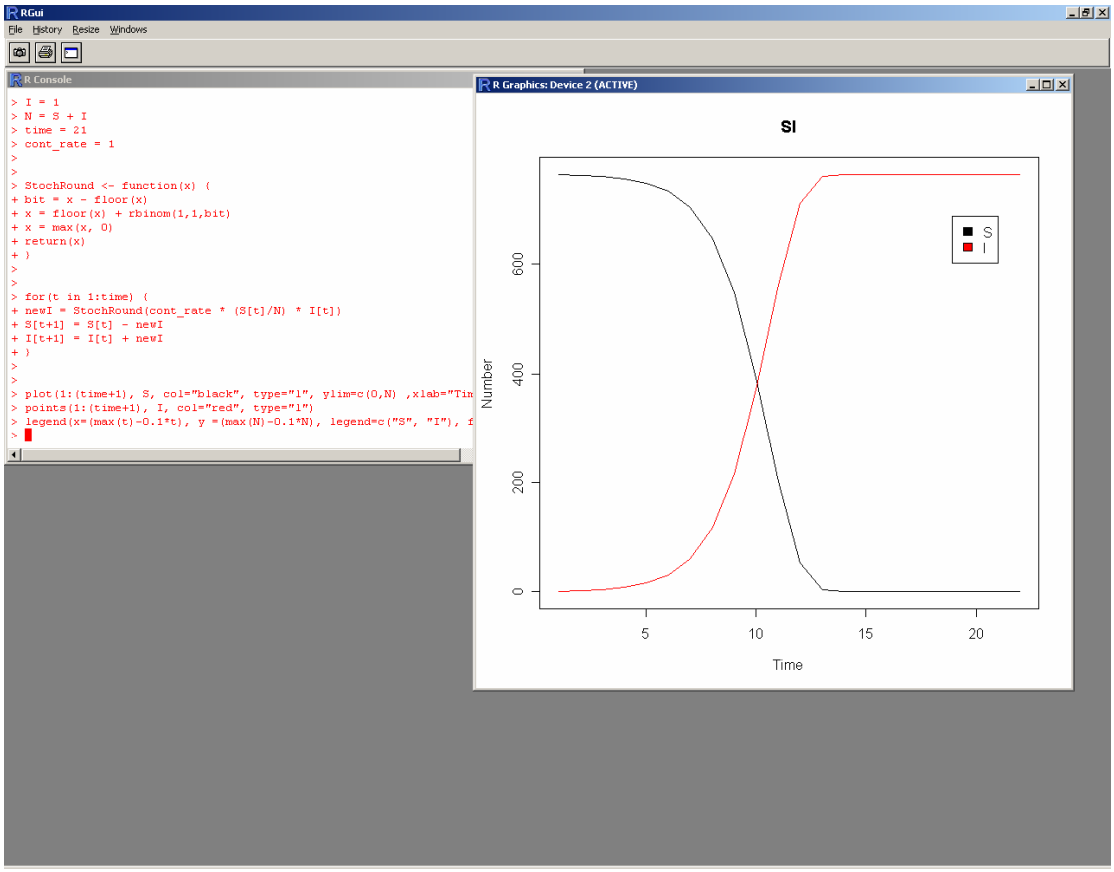
Run your model: click *RUN MY MODEL*, click *SETUP* and finally *GO*. What happens?

Gradually all go read (get infected)

Step 5. Add plots to see what is happening

It is hard to get a sense of the big picture without graphs. Right click on the **CREATE-EMPTY-POPULATIONS-PLOT** micro-behaviour to activate it. Browse for and add **ADD-SUSCEPTIBLE-TO-POPULATIONS-PLOT** and **ADD-INFECTED-TO-POPULATIONS-PLOT** to Observer (if the button reads 'Add this code to Person', click on the Observer menu at the top left of the screen).
Run the model again and sketch what you see – you may need to scroll down the screen to see the plot.

When you ran the SI model in R in the previous practical you saw:



What is the difference between these two models?

In R we make a numerical approximation of an analytical model; chance only in rounding function.

Step 6. Replace the random encounter with one based upon social networks

In above model that you have just made, each individual had an equal chance of contacting any other. This is not realistic for most disease scenarios. We will now substitute this random mixing for models where the possible contacts for each individual are constrained by what we call their 'social network.'

Inactivate the **RANDOM-ENCOUNTER** behaviour and add the **RANDOM-SOCIAL-ENCOUNTER** to **Person**.

We can incorporate a range of non-random encounters, while keeping the average number of contacts the same (we have set this figure to four). Add all of the following to your model by navigating to the web page with the micro-behaviour and open it. Click on the button labelled “Add this code to Observer”. Once they are on the screen in the middle, make sure all are inactivated except the one you want to use.

1. **INITIALISE-SOCIAL-NETWORK-SYMMETRIC**. Here each individual has the same number of potential contacts, called *acquaintances*. Disease can transfer only between individuals that are acquaintances (symmetric just refers to the fact that if A is an acquaintance of B then B is also an acquaintance of A).

Run this model and compare it to the random encounter model where any two individuals had the same chance of contacting each other. You should see a similar outcome (we are not interested in comparing them).

You can show lines of social contact (linking to the four 'acquaintances') and subsequent lines of infection by the following. Add **DISPLAY-LINE-TO-EACH-OF-MY-ACQUAINTANCES** to **Person**. Reduce the number of susceptibles to about 10 and run the model.

This is rather confusing with more than a handful of individuals so we replace lines of social contact with a variable size of the individual: the bigger the more social contacts. Inactivate **DISPLAY-LINE-TO-EACH-OF-MY-ACQUAINTANCES** and add **SET-SIZE-PROPORTIONAL-TO-NUMBER-OF-MY-ACQUAINTANCES** to **Person**. Since everyone has four acquaintances when **INITIALISE-SOCIAL-NETWORK-SYMMETRIC** is used the sizes are the same now. Run the model until it stops (**STOP-EVERYTHING-WHEN** causes it to stop after 50 cycles). Save the plot after running this by right clicking any where over the plot and choosing the ‘*copy image*’ option. You may wish to choose ‘*select*’ first and make the plot much bigger. Open up Word or your favourite word processor and paste the image of the plot into your document and write a caption.

2. **INITIALISE-SOCIAL-NETWORK-NORMAL-DISTRIBUTION-SYMMETRIC**. Here instead of each individual having the same number of acquaintances, we use a normal distribution (the familiar bell-shaped curve) with mean of four, so some individuals have more and some have fewer acquaintances. Notice the difference in when most of the popular and unpopular individuals become infected. Once again choose the ‘*copy image*’ option after right clicking on the plot and save this plot. Compare the plots in your document.

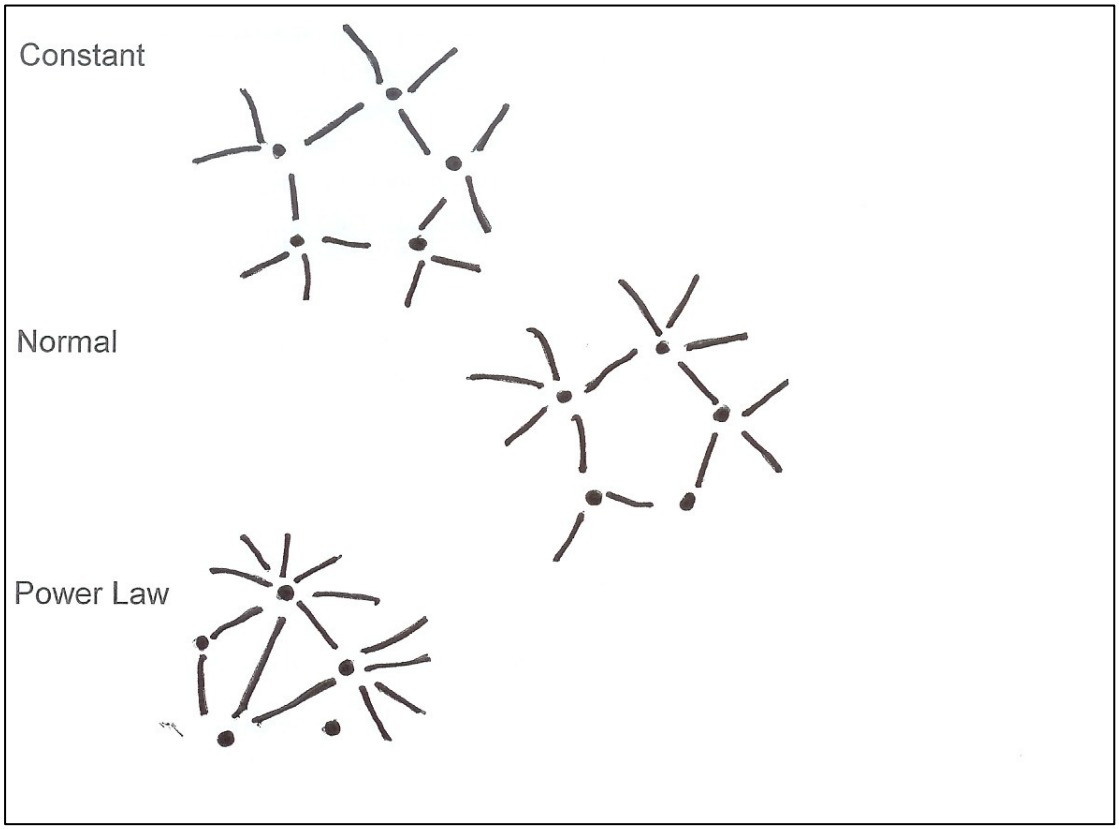
3. **INITIALISE-SOCIAL-NETWORK-POWER-LAW-DISTRIBUTION-SYMMETRIC**. Here we use a power distribution to determine how many acquaintances an individual has. Draw the three plots below and show values for critical parts of the graphs.

Constant

Normal

Power Law

Draw the social networks in the above three models that you might observe for say five individuals.



How could one have modelled this inclusion of social networks using the population model in R that we created in the earlier practicals?

More compartments with different classes of Infecteds

Apart from representing social networks, what other important factors in the spread of a disease could be represented by this new parameter?

Spatially explicit models to include population clumping (cities, farms, hospitals, schools etc.) and travel routes (e.g. air links and SARS).

In general, what do you think would be the strengths and weaknesses of these individual based models compared to analytical ones, e.g. the differential equations that we approximated in our R model?

Strengths

1. Can incorporate complex heterogeneity more easily (although perhaps only to a certain level)

2. Easier to estimate important role of probability in disease spread, e.g. does the epidemic take off or not. This can be done analytically with probability functions, but is difficult.

Weaknesses

1. Provided not too complex, analytic models can be easier to interpret and investigate.

2. More computationally demanding (although this has improved recently).

In what other areas in biology might such individual based models be useful (some clues given in website that you have been browsing)?

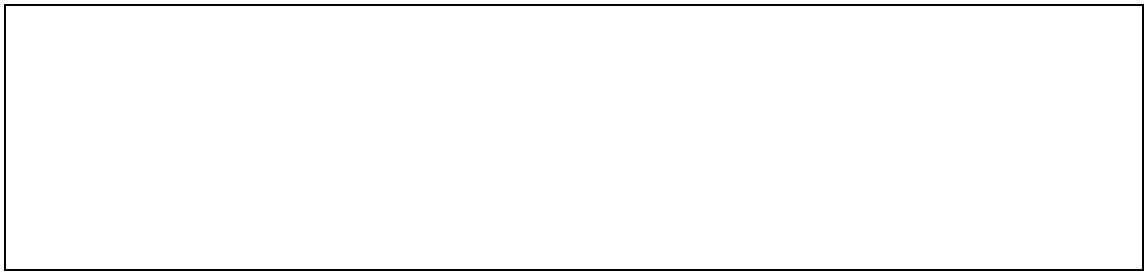
Behavioural interactions: flocking etc
Population ecology

Step 7. Save your model and email it to us.

Please send email to kenneth.kahn@oucs.ox.ac.uk attaching your final model and document with plots (with log files which you'll find in the logs subfolder of the BehaviourComposer folder).

Options if finished early or if you wish to continue another time.

The power law distribution more accurately represents the situation in a sexually transmitted disease such as AIDS in a population where some individuals have a very large number of encounters while others are monogamous or nearly so. Run the model for a second, just until you see different size images of people. You can remove individuals from the population by right-clicking on an individual and selecting from the bottom submenu *'inspect object nnn.*' Scroll down to find the field labelled 'dead' and change *false* to *true* and then type enter. Quantify the effect of removing the most promiscuous five individuals (roughly the largest ones) from the model.



In Step 3 you deactivated the **POSSIBLY-RECOVER** micro-behaviour. Activate it now. If you are curious, you can see how it works by right clicking on **POSSIBLY-RECOVER** and choosing the *Open* menu item. Activate **CREATE-INFECTION-ODDS-SLIDER** and add **CREATE-RATE-OF-RECOVERY-SLIDER** and **ADD-RECOVERED-TO-POPULATIONS-PLOT** to **Observer** in order to plot the recovered population size. Set the sliders to correspond to the same values in the SIR model you created in R (cont_rate = 1.7 and rec_rate = 0.44). Note that the equivalent of the cont_rate is the product of the values of the infection-odds-slider and the encounter-rate-slider. The equivalent of rec_rate is the reciprocal of the rate-of-recovery-slider. If the disease dies out quickly click on '*RESET*' and try again. Think about why the epidemic might die out in this model unlike the R model. You may wish to add **DISPLAY-LINE-OF-INFECTION** to Person to see a graph of the infection emerge.

Right click on **INITIALISE-SOCIAL-NETWORK-POWER-LAW-DISTRIBUTION** or the other behaviours for initialising a social network and select '*edit'*. Change the '4' in 'let average-acquaintance-count 4' to another value and click on '*Save any changes'*. Re-run your models.

Try adding **RANDOM-SPATIAL-ENCOUNTER** and inactivate **RANDOM-SOCIAL-ENCOUNTER** to explore diseases that spread spatially.

Explore the other possibilities in the BehaviourComposer.

You can obtain the software (it runs on any Windows PC) by visiting http://dfl.cetis.ac.uk/wiki/index.php/Beta_testing

Modelling the Spread of Infectious Diseases: Your Feedback on this

About this Survey

The modelling session that you have just done is part of a research project, and we would like to hear about your experiences and opinions. Questions with a * next to them are ones which you need to answer in order to carry on to the next section of the survey.

Although we ask for your name, we will treat your answers in strict confidentiality. We will, however, give a summary of the findings to Dr Belshaw.

When you have finished, click Finish after the last question to save your answers and exit. (Don't press the Cancel button at the top of your screen or close your Web browser; otherwise, you'll lose everything that you have written.) Note that once you have clicked the button to finish, you may not be able to go back and change your answers.

Thank you for your help,

The Constructing2Learn project team: Ken, Howard and Liz

Click the Next button to begin.

Modelling the Spread of Infectious Diseases: Your Feedback on this

About you...

* 1. Your name

We need to know who you are in order to match your responses with your model. However, we will not identify you by name in any published work, neither will your tutor know what you written in this survey.

* 2. What name did you give your model when you saved it?

* 3. What motivated you to study the Biology of Plant and Animal Disease?

* 4. Have you had any previous experience of computer programming?

- ◯ No experience at all
- ◯ Some experience
- ◯ Extensive experience

If you have had some or extensive programming experience, please tell us:
- The main language(s) you used
- The sorts of programs you have written

* 5. Have you had any previous experience of modelling?

- ◯ No previous experience at all
- ◯ I know something about modelling but have not done any
- ◯ I have done some modelling
- ◯ I have extensive experience of modelling

If you have had some or extensive modelling experience, please tell us what languages you used and what sort of models you created:

* 6. What is your highest qualification in mathematics?

For example: GCSE, AS Level, A2 Level, Baccalaureat, undergraduate. If you studied in another country before coming to Oxford, please name the qualification you took and the age at which you took it.

Modelling the Spread of Infectious Diseases: Your Feedback on this

About your experience creating the model today...

* 7. Who did you work with (i.e. share a computer with) in today's task?
This is so that we can match your survey responses with each other.

* 8. How far did you get through the BD3.5 worksheet?
i.e. did you complete all the steps to create both the "population" and "social network" versions? Did you have time to do any of the optional extras at the end of the worksheet?

* 9. As a result of today's session, to what extent has your understanding of the nature and purpose of modelling in epidemiology changed?

- ◯ Much better than before
- ◯ A bit better than before
- ◯ About the same as before
- ◯ A bit worse than before
- ◯ Much worse than before
- ◯ I can't really make a comparison

Feel free to clarify your answer here:

* 10. You had already modelled the behaviour of populations analytically in the spread of disease using R.

In terms of your learning, how valuable was it to construct the model in the BehaviourComposer and run it as a simulation as well as creating the analytical model? For example, did one way help you to understand the actual model better than the other?

Modelling the Spread of Infectious Diseases: Your Feedback on this

* 11. You have now modelled the spread of infectious diseases both through the behaviour of populations and through the behaviour of individuals.

In terms of your learning, how valuable was it to model the spread of infectious diseases in both these ways? Did you achieve any new insights or understandings through the individual-based model?

* 12. Thinking about your use of the BehaviourComposer tool, please rate the following aspects:

	1 (Very easy)	2	3	4	5 (Very difficult)	Not applicable
How easy it was to LEARN to use the tool	◯	◯	◯	◯	◯	◯
How easy it was to DETERMINE what each microbehaviour does	◯	◯	◯	◯	◯	◯
How easy it was to FIND the microbehaviours that you needed	◯	◯	◯	◯	◯	◯
How easy it was to MODIFY the microbehaviours to do what you wanted	◯	◯	◯	◯	◯	◯
Overall, how much you ENJOYED using the tool	◯	◯	◯	◯	◯	◯

* 13. How much help did you need? Tick as many boxes as apply.

	None: I worked it out for myself (if in a pair: we worked it out for ourselves)	I/we got help from another student (peer support)	A bit of help from a demonstrator	Quite a lot of help from a demonstrator
Help with understanding the task (what we were supposed to do)	☐	☐	☐	☐
Help with using the BehaviourComposer tool	☐	☐	☐	☐

Feel free to make any additional comments here about the amount of help that you needed:

14. The BehaviourComposer is intended to make it easier for people without programming experience to build models. On the basis of your experience today and your earlier practical using R, how far does the BehaviourComposer succeed in this aim?

Modelling the Spread of Infectious Diseases: Your Feedback on this

* 15. Given adequate time and support, would you want to use the BehaviourComposer to build other models?

- ◯ Yes, very much
- ◯ I'd quite like to
- ◯ No particular opinion
- ◯ Not very much
- ◯ Not at all

Feel free to clarify your answer here:

* 16. Overall, how much have you enjoyed today's session?

- ◯ Very much
- ◯ Quite enjoyed it
- ◯ No particular opinion
- ◯ Not very much
- ◯ Not at all

Feel free to clarify your answer here:

17. Is there anything else that you would like to tell us about your experiences today?

This is the end of the survey: now click the Finish button.