Hop, Step, Step and Jump Towards Real-World Complexity @ Delft University of Technology

Erik Pruyt*, Jill H. Slinger, C. Els van Daalen, Gönenç Yucel, Wil A.H. Thissen

August 19, 2009

Abstract

This paper deals with System Dynamics education at Delft University of Technology, the Netherlands. It focuses more specifically on the quadruple jump approach towards dealing with real-world dynamic complexity. The paper starts with an overview of the System Dynamics courses, situated within the broader curriculum. Then recent innovations in the Introductory System Dynamics course are discussed. Finally, some of the lessons learned are distilled. The rationale behind this paper are the beliefs that (higher) education determines to a large extent the quality of (the next generation) professional System Dynamics modellers, and hence, the field of System Dynamics as a whole, and that sharing (innovative and/or proven) educational practices, and exchanging actual and challenging (teaching and testing) cases may lead to further improving the quality of System Dynamics education.

Keywords: System Dynamics, Delft University of Technology, Education, Actuality

1 Introduction

The rationale behind this paper is two-fold:

- the belief that (higher) education determines to a large extent the quality of (the next generation of) professional System Dynamics modellers, and hence, the field of System Dynamics;
- the belief that sharing (innovative and/or proven) educational practices, and exchanging (teaching and testing) cases may lead to further System Dynamics education improvement.

The first specific goal of this paper is to present a large-scale[1] System Dynamics stream, embedded within two broader BSC and MSc programmes. Although this educational model works well, we do not argue that it is be the only nor necessarily the best alternative as an educational setting.

The second goal of this paper is to share some (new) teaching practices. The sharing of educational practices, and exchanging actual and challenging (teaching and testing) cases, can lead to further improvement of the quality of System Dynamics education. It may at the very least help

*Corresponding author: Erik Pruyt, Delft University of Technology, Faculty of Technology, Policy and Management, Policy Analysis Section; P.O. Box 5015, 2600 GA Delft, The Netherlands – E-mail: e.pruyt@tudelft.nl

[1] This year there are about 245 students in two introductory System Dynamics courses, 130 students in two system dynamics project courses, 20 students in an Advanced System Dynamics course, and several students doing a System Dynamics Bachelor of Science [BSc] thesis or Master of Science [MSc] thesis at the Faculty of Technology, Policy and Management of Delft University of Technology. The 245 students in the Introductory System Dynamics course is expected to be a current maximum and to reduce next year to an annual average of 150-200 students. The number of students in the System Dynamics Project and Advanced System Dynamics courses are expected to increase to annual averages of 150 and +30 students respectively. The number of BSc and MSc students wanting to apply System Dynamics in their thesis projects is also expected to increase.

to prevent re-inventing the wheel.

Although several papers discuss aspects of teaching System Dynamics at the university level (e.g. (Hovmand and O'Sullivan 2008)), there are –as far as we are aware– no contributions dealing with the System Dynamics curricula for large groups of BSc and MSc students, nor staggered approaches for ramping up to real-world dynamic complexity. Instead, the majority of tertiary education in System Dynamics occurs in specialised courses at the masters level.

In section 2 we provide an overview of the System Dynamics stream within the larger curriculum of the Faculty of Technology, Policy and Management at Delft University of Technology. A gap that existed between the Introductory System Dynamics course and the System Dynamics Project course that had to be honed and improved, and recent innovations to address this gap are discussed in section 3. Finally, some lessons learned –both from recent innovations as well as from proven practices– are presented in section 4, and conclusions are drawn and further initiatives proposed in section 5.

2 System Dynamics at the Faculty of Technology, Policy and Management of Delft University of Technology

2.1 The System Dynamics Stream within the Broader Curriculum

The Faculty of Technology, Policy and Management at Delft University of Technology offers a three-year Bachelor of Science [BSc] programme in Dutch (BSc Systems Engineering, Policy Analysis and Management – the so-called SEPAM programme), and three two-year Master of Science programmes in English (MSc Systems Engineering, Policy Analysis & Management; MSc Management of Technology; MSc Engineering and Policy Analysis – the so-called EPA programme).

All students of the SEPAM BSc programme and all students of the EPA MSc programme are required to take an Introductory System Dynamics course, and after that a System Dynamics Project course. As shown in figure 1, students can choose, after having successfully passed both mandatory courses, to take the Advanced System Dynamics course, and/or choose to apply System Dynamics in their BSc and/or MSc theses (see also (Slinger, Kwakkel, and van der Niet 2008)).

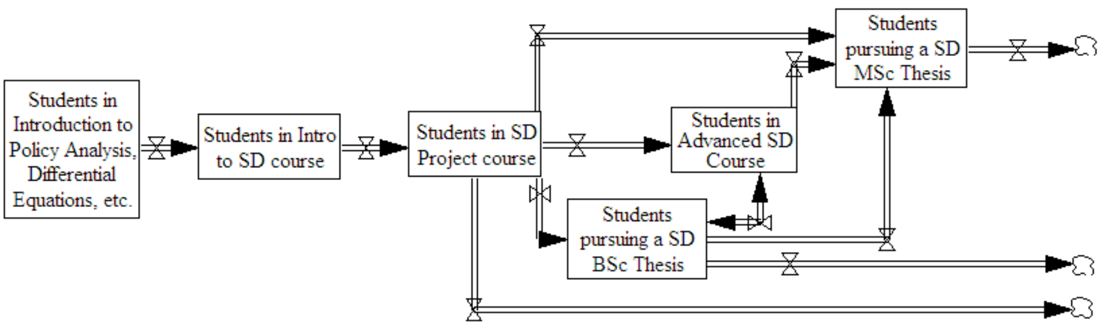

Figure 1: SFD of the core of the System Dynamics curriculum at Delft University of Technology

In their totality these System Dynamics-related courses correspond –at least for SEPAM students taking all System Dynamics courses and doing the System Dynamics thesis projects– almost to a full-time 1-year master programme in System Dynamics. However, at Delft University of Technology, these System Dynamics courses are embedded within the broader SEPAM and EPA programmes. Students in these programmes are required to take –among other things– several problem-structuring and modelling courses. Upon completion of their studies, students leave the university with a comprehensive tool box of problem structuring, modelling, problem analysis, and process design methods, and the knowledge of how to use these in an integrated way in a multi-actor context. That is one of the major strengths of this curriculum: beyond mastering the System Dynamics method (or any other specific method), students master a multitude of complementary and competing approaches and methods, e.g. Discreet Event Simulation, Multi-Criteria Decision Analysis, Conjoint Analysis, Actor-Network Analysis, etc.

Almost half of the staff of the 22-strong policy analysis section (which is responsible for all System Dynamics-related education) is actively involved in System Dynamics education and System Dynamics-related research, both methodological and applied. That means that all System Dynamics courses are grounded in, and draw upon, current applied and methodological research: applied System Dynamics research is primarily integrated into the Introductory System Dynamics course, the System Dynamics Project (policy context), and the BSc and Ma-theses projects; methodological research (e.g. on formal model analysis and model communication) is integrated in the Advanced System Dynamics course.

2.2 Before Quadruple Jumping

Before, or concurrently with, the Introductory System Dynamics Course, students follow an 'Introduction to Policy Analysis' course in which they learn, amongst other problem structuring techniques, to make Causal Diagrams, alone or in group, using laptops or smartboards. However, the emphasis in this course is on problem structuring, not on feedback loops nor on the link between structure and dynamics. Students also complete an elementary course on differential equations.

2.3 Hop: The Introductory System Dynamics Course

The Introductory System Dynamics course consists of 7 (chock-full) laptop lectures of 2 hours each, seven intensive computer practice sessions of 3 to 4 hours each, and –for the BSc students– two interim modelling tests of 2 hours each, the necessary hours of independent study, and an exam (3h) and, if needed, a retake exam (3h). Table 1 presents an indicative schedule of the Introductory System Dynamics course for BSc students.

	Topics laptop lectures	Computer lab exercises on	Tests
Week 1	Intro to systems modelling	Introductory tutorials	
Week 2	Model conceptualisation	Model conceptualisation	
Week 3	Intro to model formulation	Easy model formulation	
Week 4	Advanced model formulation	Intermediate model formulation	Test 1
Week 5	Verification and validation	Advanced model formulation	
Week 6	Model use	Verification and validation	
Week 7	Integrated modelling	Model use and difficult cases	Test 2
			Exam
			Retake Exam

Table 1: Overview of the Introductory System Dynamics course for the BSc students

During the academic year 2008-2009, the number of students enrolled in the Introductory System Dynamics course amounted to 245 students: 210 BSc students and 35 MSc students. All students starting the course are pre-tested and all students taking the exam are post-tested [Note: results have not been analysed yet but may be discussed briefly in the final version of the paper].

Section 3 deals with several innovations in the Introduction to System Dynamics course introduced recently to ramp up the System Dynamics modelling skills of the students to the level necessary to perform well enough during the System Dynamics project.

2.4 Step: The System Dynamics Project

After successfully passing the Introductory System Dynamics course, students enter the System Dynamics Project. Based on a case description of about 15-20 pages, students work in pairs to make a System Dynamics model, to validate the model, to use the model to analyse the problem situation, and to report on the results and recommendations (to a fictitious 'problem owner' or client). They also have to write a reflection on (their own) modelling to strengthen their reflective skills. For an in-depth presentation of the System Dynamics project and the reflection on modelling, see (Slinger, Kwakkel, and van der Niet 2008).

The emphasis in this course is on constructing and using a problem-relevant model. The context of the problem-owner requires them to use problem structuring and advisory skills in conjunction with modelling skills.

The underlying model of the System Dynamics project is much larger than the largest models dealt with in the introductory course. The modelling context is also much broader and fuzzier than any of the 'difficult cases' from the Introductory System Dynamics course. The project case contains relevant and irrelevant information, uncertainties, some contradictions, and of course, information needed to specify the System Dynamics model. The student pairs are supervised weekly –over a period of 7 weeks– by student assistants, PhD students, and lecturers. The project is also an excellent learning opportunity for the student assistants supervising project groups.

During the academic year 2008-2009, the number of students participating in the System Dynamics Project course amounted to 130 students (100 SEPAM BSc students and 30 EPA MSc students).

2.5 Step: The Advanced System Dynamics Course

The advanced System Dynamics course focuses on the theoretical and practical basis for selecting, building, validating, analysing and communicating systems models. It allows students to refine their System Dynamics-related knowledge and skills. The course comprises the following topics: justification, use of data, explaining structure-behaviour relationships, validation, formal/behavioural analysis, interactive learning environments and games, group model building, and choosing modelling methods. The theory underpinning these topics is applied in a number of assignments related to a case which runs in parallel to the lecture series. Students are expected to design and implement a strategy for communicating the structure, behaviour and results of their models and to use this in their final presentations. Guest lectures by 5 System Dynamics practitioners and researchers are part of the course. This year, 19 students take the Advanced System Dynamics course.

2.6 And Jump: Ba and Ma Thesis Projects

The major problem encountered by thesis students is the lack of explicit or implicit boundaries. For most students, starting a System Dynamics thesis, this corresponds to jumping into the void.

Even after taking all System Dynamics courses, students only seem to learn from their own experience that one of the major difficulties of doing good applied System Dynamics research has to do with the lack of definition of boundaries, relationships, and issues. In the Introductory System Dynamics course, problem descriptions, model boundaries, and model formulations are explicitly given. In the System Dynamics Project, model boundaries and formulations are implicitly given. Students are challenged to think about the choices made in the report back to the client. In the thesis projects, students have to describe their own problem, set their own model boundaries, and come up with their own model formulation.

Students are free to choose their topic. Some students choose to work for a specific problem owner facing a particular problem i.e. using System Dynamics in an advisory function (Mayer, van Daalen, and Bots 2004). Other students come up with research problems of their own. And still other students work on issues directly or indirectly suggested by lecturers (e.g. 5 MSc students are currently developing more detailed models of test/teaching cases mentioned in the last bullet of section 3).

The main difference between BSc and MSc thesis students is their maturity. Many MSc students pursuing a System Dynamics thesis have also completed the Advanced System Dynamics course, contrary to the BSc students.

3 Recent Innovations in the Introductory System Dynamics Course

In the past, the technical, rather than the conceptual, modelling skills of part of the students passing the Introductory System Dynamics course were problematic for the System Dynamics project. In other words, the lack of technical modelling skills made the project difficult for these students who had to improve their skills in using the software as well as learn to deal with broader boundaries, fuzzier descriptions, and the embedding of a model in an advisory process to a client. This misfit may have been caused by:

- the gap between the small, technical exercises dealt with during the non-mandatory computer labs of the Introductory System Dynamics course and the large case study of the System Dynamics Project;
- the lack of computer-based testing of students' modelling skills (mainly because of practical/technical reasons), and hence, the lack of incentive for students to invest sufficiently in applied System Dynamics modelling skills during the Introductory System Dynamics course;
- the possibility to compensate for poor performance on the System Dynamics modelling part of the exam with high performance on the mathematics, control engineering, and theoretical System Dynamics parts of the exam.

In order to ramp up their practical System Dynamics modelling skills, the following innovations/changes have been introduced over the last 2 years (more or less in chronological order):

- More difficult exercises and cases were included in the computer labs and exercises book (Pruyt, van Daalen, Phaff, and Yucel 2008) to narrow the gap between the Introductory System Dynamics exercises/cases on the one hand and the System Dynamics Project case study on the other hand.
- The number of assisted computer lab hours of the Introductory System Dynamics course was doubled from 2 hours per week to 3-4 hours per week (in theory assistance corresponds to about 1 student assistant or lecturer per 25 students, in practice to 1 per 20 students).
- Extensive computer-based testing of practical System Dynamics modelling skills during the examination of the Introductory System Dynamics was introduced. A special 'closed exam mode' was developed for this purpose. When the computer network is in exam mode, students cannot communicate and/or access the internet or network drives, except for storing models and runs on an exam drive, accessible at all times by the lecturer. Tests and exams now take between 2 and 3 hours and consist of 1 major modelling question (on more than half of the total grade of the test/exam) and 20 Multiple Choice questions [to test their knowledge, diagramming and reflective skills, and insight into the link between structure and behaviour]. The major modelling question consists of a story and several subquestions to guide students through model construction, testing and use of a relatively large System Dynamics model (of the same size and level of difficulty as the difficult exercises/cases in the computer labs – see (Pruyt 2009c)).

  This way, students have a direct incentive to acquire the necessary modelling skills: they know beforehand that they can only pass the Introductory System Dynamics course if their practical System Dynamics modelling skills are up to scratch.

- Traditional (sit-watch-listen) lectures have been replaced by laptop lectures to which students bring their laptops (see figures 2a and 2b). These laptop lectures have been introduced to:
  - activate students during the lectures (not only actively listening and participating, but actively *modelling* in class)
  - accelerate the learning process through 'demonstration-imitation-and-doing' in class
  - address the inappropriateness of the projection facilities in our largest computer room
  - provide immediate feedback on collective mistakes and problems (about 30% of the students make the same mistakes which really counts with groups of 200 students), allowing for learning from mistakes made by others
  - further integrate of lectures and computer labs by:
    * discuss and further explanation of System Dynamics models made during the computer labs and comparison of models made by lecturer and students
    * easily extend small models made during the computer labs to large real-world models without losing students along the way.

(a) Laptop lectures of the Intro SD course (b) Laptop lectures (c) EPA students playing FishBanks

Figure 2: System Dynamics BSc and MSc education at Delft University of Technology. Source figure 2(a) and 2(b): (Onderwijskundig Centrum Focus 2009)

Currently, the laptop lectures still suffer from several start-up problems, often related to the required technical infrastructure (insufficient number of power plugs and internet plugs and/or wireless access points, insufficient server capacity for server-based applications, . . .), but also related to the required contents and teaching style (smaller exercises, slower pace, and more patience on the part of the lecturer).

- Lectures have been recorded and uploaded on the course site, in order to allow students to watch / review the lectures whenever and where they want. The main reasons for recorded the lectures were:
  - the large number of BSc students (and the even larger amounts of students expected in the coming years) versus the relatively small lecture halls,
  - the density and difficulty of the course (a large amount of material is covered in a short period of time), and related to that,
  - to offer students the possibility to catch up after missing one/some/all lecture(s) and to review the lectures before the exam. Some 160 active BSc students logged a total of 730 times into the lecture streaming part of the course site in just 2 months).

- Before the academic year 2008-2009, the Introductory System Dynamics course was part of a larger course module consisting of three separate components given in parallel: a differential equations part, a System Dynamics part, and a Control Engineering part. The examination covered all contents of the module, which meant that students could compensate for bad grades on one part by good grades on other parts. From the academic year 2008-2009 onwards, Control Engineering was dropped, and the Differential Equations and System Dynamics parts became two separate (sequentially-linked) courses. Henceforth compensation is impossible (both in a positive and negative sense), and the yardstick for passing the Introductory System Dynamics course and being admitted to the System Dynamics Project is now unambiguously 'sufficient System Dynamics modelling skills'.

- And last but not least, (almost) all new exercises, cases, and exam questions of the Introductory System Dynamics course are based on 'hot' issues. Exercises and cases used in weeks 4, 5, 6, 7 of the introductory System Dynamics course –as well as all test and exam models– deal with actual, relevant, real-world issues of increasing complexity. Recently developed cases include: the near-collapse of the Fortis Bank[2] (see (Pruyt 2009d)), the revision of the Dutch soft drugs policy[3] (see (Pruyt 2009b)), the raw materials problem of a large-scale transition to electrical vehicles[4] (see (Pruyt 2009c)), the recent cholera outbreak in Zimbabwe[5] (see (Pruyt 2009a)), the recent ice skating hype in the Netherlands[6] (see (Pruyt 2009c)), the current redevelopment of social housing districts in the Netherlands[7] (see (Pruyt 2008a)), the recent and future conflict between food security and energy security as in (Pruyt 2008b), and the issue of waiting lists in Dutch hospitals. For more information on and examples of 'hot' real-world teaching/testing cases see (Pruyt 2009c).

4 Lessons Learned

- The main problem of intensive courses concentrated in only seven weeks is that the time to digest the material is (too) short. Luckily, System Dynamics students at Delft University of

[2]The System Dynamics model of this case was developed on 28 September 2008, when the governments of the BeNeLux countries met in a great hurry to rescue the Fortis bank, in order to gain a better understanding of the dynamics of a bank crisis and to test policies for saving a bank like the Fortis bank. The model was turned into an exam/teaching case (and was used for the EPA exam of 23 October 2008). The case is interesting because the topic is very actual and important, the model is small and simple, can generate different dynamic behaviours and is useful for exploring possible policies.

[3]On 21 November 2008, a 'Soft Drugs Summit' ('*wiet top*') was held in the Netherlands to discuss the future of the Dutch policy of tolerance related to soft drugs, known as the Dutch 'gedoogbeleid'. The day after the highly mediatised soft drugs summit, two qualitative System Dynamics models based on the two dominant (and strongly opposing) lines of reasoning were created. The model corresponding to the point view of the proponents of legalisation was turned into a testing/teaching case (used for the first SEPAM BSc test on 27 November 2008). At the time, the case was actual and relevant for Dutch students and policy makers.

[4]Enexis, a Dutch Distribution Network Operator, considers developing a 'Smart Mobile Grid' in which Electric Vehicles are used among else to improve their grid usage, to store electricity, and to decouple load and large-scale intermittent renewable energy generation. A simplified model was developed concerning the coupled dynamics of a large-scale transition from conventional vehicles to electrical vehicles, the use of electrical batteries (previously used by the electrical vehicles) to decouple intermittent supply and demand in the electricity grid, the impact of electrical vehicles on the grid, and the accelerated depletion of lithium resources. It was turned into a testing/teaching case (used for the second SEPAM BSc test on 21 December 2008).

[5]By the end of December 2008, alarming reports and articles concerning the cholera outbreak in Zimbabwe received lots of attention in the international media. By that time 30000 cases of cholera infections and 1600 cholera deaths had been reported. In the first week of January 2009, a System Dynamics simulation model related to this cholera epidemic was created which was turned into an exam case (for one of the four versions of the SEPAM BSc exam of 14 January 2009). Although the model has not been validated yet by Cholera experts, this case is especially interesting for teaching/testing because of the resulting dynamics: without policies, only taking the medium term dynamics or the long term dynamics would lead to different conclusions.

[6]On 11 January 2009, at the end of the recent Dutch ice skating hype, a System Dynamics model was developed concerning the ice craze and the resulting boom of skates sales during cold waves. It was turned into a testing/teaching case for one of the four versions of the SEPAM BSc exam of 14 January 2009.

[7]The redevelopment of pre- and postwar social housing districts is currently 'hot' in the Netherlands. A simplified version of the 'District Housing' model presented in (Pruyt 2008a) was developed and turned into a teaching/testing case (used for the BSc retake exam of 18 August 2008).

Technology have another three weeks to digest the material and practice before their exam, and then a sequence of further courses in their curriculum to deepen their understanding.

- Laptop lectures require a good infrastructure (enough access points and power plugs), and a slower pace during the lectures, and hence, enough time and patience. Although laptop lectures require a slower pace during the lectures, the total speed of learning is increased (compared with traditional lectures).

- Introducing laptop lectures would not have been necessary if computer halls with good projection facilities and equipment for more than 200 students would have been available. During the first year of their introduction, laptop lectures still posed many problems. Next year, they need to be further improved.

  Nevertheless, laptop lectures are good for doing small exercises, for collectively correcting mistakes (and learning from mistakes made by others), for direct modelling interactions between large groups of students and the lecturer, for ramping up from small exercises to larger models.

- Teaching and testing cases are –as much as possible– based on 'hot' issues because this illustrates the relevance of System Dynamics modelling for current and complex issues, teaches students what System Dynamics models can really be used for, and shows students what high-level System Dynamics models of real-world issues look like. Additionally, it spurs students on to look at current issues from a systems modelling perspective and helps students to connect news stories to potential System Dynamics models, and how these models could be useful, and above all, to enthuse students for using System Dynamics modelling in dealing with real-world issues whenever it is appropriate.

- Although actual real-world cases have been found to be very motivating, they are also more difficult than exercises developed to test and practice, because these actual real-world cases must be sufficiently close to the real-world case to be credible and relevant and so are complex.

- The major problem of developing good real-world testing/teaching cases/exercises for an introductory course is that it is extremely time-consuming, yet needs to be done rapidly in order to able to use 'hot' cases. Hence, it may be desirable for university lecturers of Introductory System Dynamics courses around the world to join forces, form a network, and share relevant real-world test/exam cases.

5 Conclusions

At the Faculty of Technology, Policy and Management of Delft University of Technology, a full System Dynamics stream is offered within the broader curriculum. Consequently, students learn to apply more than just one method. They also learn to apply the System Dynamics method (in depth) thanks to the Hop-Step-Step-Jump approach in which, step by step, the level of difficulty and (real-world) complexity is increased.

The System Dynamics courses at Delft University of Technology are intensive, both for students and for lecturers, and are focussed on gradually increasing students' skills to the level required to deal with real-world complexity. The large groups of students provide a challenge in the intensive, interactive and difficult System Dynamics courses: assignments and tests/exams require lots of modelling hours/student, and therefore many computers and lots of assistance. Moreover, large groups increase the burden for lecturers to such an extent, that different teaching approaches are required. Since group sizes are not expected to drop in the coming years –on the contrary– several changes have been introduced in the mandatory Introductory System Dynamics course.

The main result of these innovations in the Introductory System Dynamics course is that modelling skills are rapidly ramped up to the level required for the System Dynamics Project: at the end of seven intensive course weeks and three weeks to digest, most students are capable of building System Dynamics models of reasonably complex, real-world issues.

Many of the measures introduced in the Introductory System Dynamics course –especially the (more difficult) actuality-based teaching/testing cases– have strengthened the reputation of the Introductory System Dynamics course as a difficult course. At the same time, goals have been clarified: System Dynamics modelling skills are now unarguably *the* goal. Consequently, students work harder and in a more focussed way, which has resulted in an improvement in their practical System Dynamics modelling skills and in an increased pass rate.

Currently, the emphasis in the System Dynamics stream lies on the two mandatory courses in the first part of the curriculum where the focus lies on developing the modelling skills of all students. In the coming years, the number of BSc and MSc students wanting to apply System Dynamics in their thesis project is also expected to increase. Hopefully that will also result in more of our top students wanting to pursue a PhD in System Dynamics[8].

References

Hovmand, P. S. and J. A. O'Sullivan (2008, Winter). Lessons from an interdisciplinary system dynamics course. *System Dynamics Review 24*(4), 479–488. 2

Mayer, I., C. van Daalen, and P. Bots (2004). Perspectives on policy analyses: a framework for understanding and design. *International Journal of Technology, Policy and Management 4*(2), 169–191. 4

Onderwijskundig Centrum Focus (2009, January). Successen met ICT in het onderwijs aan de TU Delft. grassroots project 2007-2008. Delft.

Pruyt, E. (2008a, July). Dealing with multiple perspectives: Using (cultural) profiles in System Dynamics. In *Proceedings of the 26th International Conference of the System Dynamics Society*, Athens, Greece. 7

Pruyt, E. (2008b, July). Food or energy? Is that the question? In *Proceedings of the 26th International Conference of the System Dynamics Society*, Athens, Greece. 7

Pruyt, E. (2009a, July). Cholera in Zimbabwe. In *Proceedings of the 27th International Conference of the System Dynamics Society*, Albuquerque, USA. 7

Pruyt, E. (2009b, July). The Dutch soft drugs debate: A qualitative System Dynamics analysis. In *Proceedings of the 27th International Conference of the System Dynamics Society*, Albuquerque, USA. 7

Pruyt, E. (2009c, July). Making System Dynamics Cool? Using Hot Testing & Teaching Cases. In *Proceedings of the 27th International Conference of the System Dynamics Society*, Albuquerque, USA. 5, 7

Pruyt, E. (2009d, July). Saving a Bank? The Case of the Fortis Bank. In *Proceedings of the 27th International Conference of the System Dynamics Society*, Albuquerque, USA. 7

Pruyt, E., C. van Daalen, W. Phaff, and G. Yucel (2008). *Exercises Continuous Systems Modelling, System Dynamics SPM2313 / EPA1321*. Delft University of Technology. 5

Slinger, J., J. Kwakkel, and M. van der Niet (2008, August). Does learning to reflect make better modelers? In *Proceedings of the 26th International Conference of the System Dynamics Society*, Athens, Greece. 2, 4

[8]Although several PhD students apply System Dynamics modelling, few PhD students focuss solely on advancing the SD method/domain.