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PERSPECTIVES ON TEACHING MODELING AND SIMULATION IN A DEPARTMENT OF COMPUTER SCIENCE

Armin Kashefi
Faris Alwzinani
David Bell

Department of Computer Science
Brunel University London
Uxbridge, UB8 3PH, UK.

ABSTRACT

In this paper, we share our approach to teaching conceptual model development and simulation modeling at a Department of Computer Science in the UK. We explore the challenges and opportunities we face teaching static and dynamic modeling to the 2nd and 3rd year undergraduate students. While our Business Computing students tend not to be as technically savvy as our Computer Science students, which at times limits the technical complexity of what we can cover in our courses, we designed the Business Analysis and Process Modeling course as a tool to empower students to analyze and discuss business problems in-depth. The paper reports on the design and findings of the undergraduate teaching of modeling and simulation content. We finalize the paper by providing some concluding remarks and future directions.

1 INTRODUCTION

In this paper, we share our approach to teaching modeling and simulation (M&S) at the Department of Computer Science at Brunel University London, UK. Our undergraduate Business Computing (BC) program is aimed at students to develop an understanding of the underlying organizational business processes that enable the Information Systems users to carry out the business of an organization effectively and efficiently. The BC program is designed to provide students with a broad knowledge of the three related areas of computing (Computer Science), system development (Business), and project management. Computing topics cover the fundamental properties of software artifacts, namely algorithms, programming, and network architectures. System development approaches cover design methods, usability engineering, M&S techniques and human and organizational aspects of computer-based systems. Appreciation of project management issues arising from team-based software development is also a key feature of the degree.

Our Business Computing students tend not to be as technically savvy as our Computer Science students, which at times limits the scope and technical complexity of what we can cover in our modules. To address this limitation, we designed the Business Analysis and Process Modeling module as part of a 2nd year undergraduate program as a tool to empower students to analyze complex systems and discuss business problems in-depth.

This paper aims to convey insight into education aspects pertaining to teaching modeling and simulation (M&S) concepts within a non-M&S specific department, Computer Science. This is motivated by the scarcity of suchlike examples. It highlights course goals and characterizes course elements such as learning outcomes (LOs), specifics on module delivery, deliverables, lectures and laboratory sessions. This paper details the design and findings from years 2 and 3 of the undergraduate teaching of M&S content to Business Computing students. The intention is not to suggest that this course set-up is any better (or worse) than other methods of teaching M&S. Instead, it attempts to contribute to the Simulation

Education by sharing the outcomes and experiences throughout this process in order to promote M&S subjects in education.

After briefly reviewing some of the relevant literature in the next section, we describe how we design, teach and assess teach model development and simulation modeling to our 2nd year undergraduate students. In section 4, we explain how 3rd year Business Computing students apply the lessons learned in their final year simulation projects. We finalize the paper by providing some concluding remarks and pointers to future work.

2 RELEVANT LITERATURE

Teaching modeling and simulation (M&S) in education varies based on the academic discipline. Historically, M&S has been considered as an essential tool in many disciplines or application domains. It has been popular in the engineering field including industrial engineering and production engineering (Smith et al. 2017; Schultz and Geiger 2005; Altiok et al. 2001). Simulation courses being taught in engineering departments tend to emphasize engineering applications of simulation to solve realistic problems in industrial context (Roberts et al. 1982). Those being taught in Computer Science departments are more theoretical oriented towards the differentiation between simulation languages or between discrete and other simulation types (Saltzman and Roeder 2013; McKenzie et al. 2015; Mielke et al. 2009).

A panel discussion on education in simulation by Altiok et al. (2001) highlights different approaches to teaching M&S that rely on the instructor's background, type of students and course program. Other methods include storytelling and simulation creation (Padilla et al. 2016; Padilla et al. 2017) or the development of a multidisciplinary approach to M&S graduate education (Mielke et al. 2009). Concerning Business/Business Computing students, M&S courses have been focusing on simulation methodologies, structured thinking and how to present the complexity of a simulation model in oral and written forms (Mustafee et al. 2006). These skills are not only about how to design, build and run simulation models but how a student after graduation will be able to benefit from these skills to make formal presentations, write technical reports and communicate clearly with domain experts (Jacobson et al. 1994).

In their broadest sense, M&S courses provide undergraduate students with conceptual and technical modeling skills (Padilla et al. 2016; McKenzie et al. 2015; Mielke et al. 2009). Through the M&S course students should be able to acquire a better understanding of complex systems and technical capabilities to model, analyze and manipulate such systems (Altiok et al. 2001). They help students develop computational thinking which is central to the Computing curriculum (Kazimoglu et al. 2012).

This paper is positioned within the realm of existing studies that teach simulation. The focus will be on teaching / learning of BPMN and Simul8 versus other tools or methodologies (Padilla et al. 2016; Padilla et al. 2017; Dahlstrom 2014). These types of courses can present unique challenges as business computing students may not possess the same technological and computational skills compared to those in Computer Science program. Nonetheless, simulation can be an influential tool for business decision making and can be used to develop students' analytical and computational thinking skills.

3 UNDERGRADUATE MODULE: BUSINESS ANALYSIS AND PROCESS MODELING

3.1 Course Overview and Goals

The Business Computing program at Brunel University London does not tend to attract the university's most programming savvy students. Many of the students choose this degree to learn what change can do to an organization and how Information Systems can be aligned and integrated in a process-oriented way. Our first year modules cover the needs of students from a wide variety of backgrounds and with diverse computing experience. By the end of the first year, students have covered the fundamental concepts of computer science and the computer-based systems necessary in business. In the second year, students will further specialize in the area of Business Computing including systems analysis and design to better comprehend the changes in processes and technologies that organizations must make if they are to get the best from their information.

As part of these efforts, the "Business Analysis and Process Modeling" module (code name: CS2006) was set up to provide students with a theoretical and practical understanding of the role and purpose of modeling and simulation in the context of Information Systems development and evolution. Any student who takes this module can expect to attain the necessary skills relevant to the role of a Business Analyst in an organization. The skills are mainly related to (a) analysis of typical real-world business scenarios with the aim of proposing relevant improvements and (b) the effective communication of the results to both technical and business sides of an organization. This module will be taught through lectures and laboratory sessions.

Regardless of the module or program of study, there are learning outcomes (LOs) that students must meet in order to be awarded the credits which comprise the module and program of study. For Business Analysis and Process Modeling module students must demonstrate ability in a number of different areas by carrying out quite complex tasks. Accordingly, they must be able to (LO1) describe the concepts, principles and perspectives that underpin business analysis and the development of associated models; (LO2) produce conceptually sound models that represent typical business analysis problems using appropriate business analysis tools and techniques; and (LO3) critically evaluate issues and problems that arise during the representation of organizational processes and knowledge while providing reasoned explanations to attempt to resolve them.

The assessment is in two parts: a business modeling and simulation coursework assignment and a 2-hour unseen end of module examination. The coursework assignment is split into two parts: Task 1 and Task 2. Task 1 is related to the business process modeling part of the coursework (i.e. static modeling), while Task 2 is related to the simulation modeling part of the coursework assignment is split into two tasks, the final coursework grade will reflect a combination of the marks obtained in both Tasks 1 and 2.

3.2 Module Organization and Pedagogical Details

This section explains the module content and the way it is organized in a full academic year.

3.2.1 Lecture Sessions (Full Academic Year)

Lectures in CS2006 focus on the role of a business analyst and their importance as a metaphorical bridge between different departments and professionals. A total of 16 lectures (1 hour each) are scheduled across two terms and the topics covered are introductory material to 4 broad areas namely business analysis theory and practice, business process management, static and dynamic modeling and business systems integration. Table 1 shows the breakdown of lecture sessions by topics. The aim is to familiarize students with current trends and practices in the industry concerning business analysis and related topics and business skills.

The static and dynamic modeling topics, in particular, are split in three parts. Accordingly, 'Introduction to Modeling' and 'Business Process Modeling' lectures are given in the first term. The aims of these lectures are twofold: to equip students with fundamental understanding and knowledge of modeling (i.e., how business process modeling is used to represent organizational processes), and to explain how businesses model their processes (i.e., steps need to be taken in implementing business process improvement).

Table 1. Lecture coverage.

Lecture Topics	**Lecture coverage**
Business Analysis Theory and Practice	• Introduction to Business Analysis • Analyzing organizations • Business Change projects • Requirement engineering
Business Process Management	• Introduction to business processes • Business process improvement
Static and Dynamic Modelling	• Introduction to modeling (General) • Business process modeling (Static) • Business process simulation (Dynamic)
Business Systems Integration	• Business systems integration • Overview of enterprise systems

The 'Business Process Simulation' (BPS) is taught in the second term and focuses on dynamic modeling, and in particular, Discrete-Event Simulation (DES) modeling. This lecture explains the purposes, benefits and outcomes of business process simulation. For instance, during this lecture, students will learn about methodologies most employed in the conduction of simulation projects and the key stages/processes involved in doing BPS namely: (1) Building a Model (AS-IS), (2) Running the Model, (3) Analyzing the Performance Measures (KPIs), and (4) Evaluating Alternative Scenarios (TO-BE). Moreover, as part of Business Process Redesign and Improvement initiatives, BPS allows representation of processes, people and technology in a dynamic computer model (Banks et al. 2013; Brooks and Robinson 2000; Robinson 2004).

Figure 1 lays out the course progression over time. As it is seen, while the lectures cover the theoretical/conceptual aspects of M&S and business analysis in general, the static and dynamic laboratory sessions, during the first and second terms respectively, enable students to develop their modeling skills as well as analytical thinking.

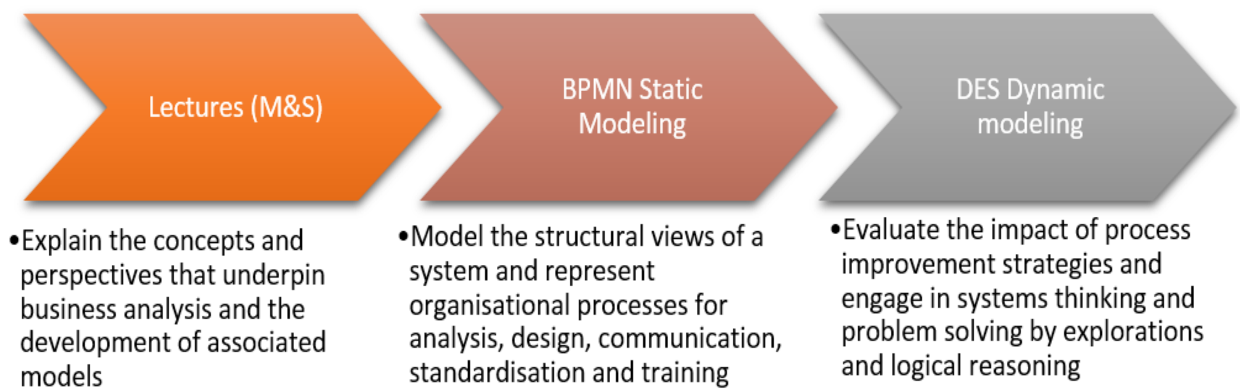

Figure 1: Course progression.

3.2.2 Laboratory Sessions in First Term (Focusing on Static Modeling)

The Business Analysis and Process Modeling module (CS2006) is taught across two terms where much of the work by students is done independently. As mentioned previously in section 3.2.2, the lectures during the first term aim to provide students with a better understanding of business process management and improvement as well as why and how modeling, and particularly static modeling, is used. In the weekly 2 hours laboratory sessions of the first term, the software package used for static modeling is Microsoft Visio and the modeling technique follows the Business Process Modeling Notation (BPMN) methodology. BPMN is a standardized notation for creating visual models of business or organizational processes. It visually depicts a detailed sequence of business activities and information flows that business analysts can use to develop processes, which technical people can use for implementation, and that business users can use to manage and oversee. This helps students to understand a complex problem and the potential solutions through abstraction and is therefore an important component in system engineering and enterprise modeling. A total of 8 laboratory sessions are scheduled for the first term which provides a forum in which students can be guided in their development of critical thinking skills in relation to business analysis and process modeling.

Starting with basic BPMN concepts students initially learn how to build simple process models through lab exercise such as creating a BPMN diagram for a process "Prepare Coursework". Over the course of two months, students will progressively learn about intermediate and advanced BPMN notation. Building upon their initial models, student acquire the necessary skills to add complexity and depth to their models. Of a 2-hour laboratory session the first 30 minutes are spend by the module leader on teaching new concepts. For the remaining time students are expected to complete lab exercises. Also, students will have the opportunity to discuss these exercises in small groups and reflect on their learning. There are always four graduate teaching assistants (GTAs) available in each laboratory sessions to support students with their BPMN modeling.

3.2.3 Laboratory Sessions in Second Term (Focusing on Dynamic Modeling)

As stated previously in section 3.2.2 in second term lectures cover dynamic modeling, its advantages and the ways in which business systems integration is achieved through both business and technical innovations. The laboratory sessions in the second term focus on more advanced modeling techniques and students have the opportunity to investigate how business systems can be modeled dynamically. The simulation software of choice is SIMUL8 which is a computer-based modeling package (Hlupić and Vukšić 2004; Fousek et al. 2017). This software has been adopted by the Department of Computer Science as it supports a number of essential functionalities. For instance, it provides an easy-to-use, discrete-event simulation package that is used for supporting various decision-making activities (Mustafee et al. 2006). The software incorporates programming language (visual logic) and model visualization capabilities that enable a user to create accurate, flexible, and robust simulations. Furthermore, it provides helpful defaults to allow quick initial model building. Lastly, performance data can be collected as required. A total of 9 laboratory sessions are scheduled for the second term. Students are provided with SIMUL8 workbooks, exercises and sample SIMUL8 models to learn about dynamic modeling and advance their modeling techniques.

In addition to following the SIMUL8 workbook to understand the overall meaning of dynamic modeling and the steps involved, students also needed to learn about complementary topics. These topics include resources handling, prioritizing, labels and KPIs. After learning about the concepts and modeling simple workbook-based scenarios, students are given a chance to model more advanced scenarios. In this way, they can apply the lesson learned and reflect on their learning process, and if need be, reviewing the materials again. Students are advised to try the proposed complex scenarios in order to become familiar with the expectation of the coursework assignment. Similar to the first term, there are always four GTAs available in each laboratory session to support students with the SIMUL8 software. Nevertheless, unlike the first term, there is no presentation scheduled for the laboratory sessions. Students will have 2 hours to learn about dynamic modeling either individually or in small groups.

3.3 Modeling and Simulation Pedagogical Goals

Business Computing students are unlikely to find themselves in highly technical jobs after graduation. Rather, they are receiving degrees in Business Computing and should be expected to start a career as a business or system analyst. Therefore, students must be able to produce conceptually sound process models that represent typical business analysis problems using appropriate business analysis tools and techniques. The Business Analysis and Process Modelling module helps students to acquire detailed knowledge about static and dynamic modeling methods for describing business processes. While BPMN is considered as a standard of static process modeling, simulation modeling is an excellent tool for investigating and adjusting dynamic processes. Specifically, when conducting experiments within real systems is too expensive, time-consuming, or hazardous, simulation becomes a powerful tool. The aim of simulation is to support objective decision making by means of dynamic analysis, which allows decision makers to safely plan their operations, and to save costs. simulation helps students to acquire skills and competencies in scenarios similar to those of the real world (Wing 2006; Dobson & Shumsky 2006).

To this end, the Business Analysis and Process modeling module aims to equip students with analytical thinking, problem-solving skills and a range of modern analytics tools and techniques that assist the process of decision making. We help students to answer the following questions through simulation modeling:

- Why does waiting time increase with utilization in systems with variability?
- What is the best strategy for resource utilization? (e.g., number of required resources)
- Why does waiting time increase when the inter-arrival and/or service variability increase?
- How long must a modeled system run before the observed average is likely to approach the steady-state average?
- What is the difference between steady-state and transient results? (e.g., starting from an empty system versus an equilibrium start)

The focus of the module is therefore on training students for precise analytical and computational thinking (Wing 2006). Computational thinking is about breaking down tasks into a logical sequence of steps to reach an objective. It is about choosing an appropriate representation for a problem or modeling the relevant aspects of a problem to make it tractable. Also, it is about modularizing something in anticipation of multiple users or in anticipation of future use. Integrating computational thinking into modeling and simulation helps students to develop a new skill set that is increasingly relevant for our digitalized society (Garneli & Chorianopoulos 2017).

3.4 Student Deliverables

For Task1, students are given an imaginary business scenario which they need to analyze and model to answer 4 wide-ranging questions using the BPMN notation. For the first two questions students are required to prepare several detailed diagrams (e.g., collaboration diagram, and organizational collaboration) using different entities (e.g., black box/ white box pools). For the third question, students need to reflect on the lessons learned throughout the first term to explain the relative advantages and disadvantages of the diagram representations done in Question 2. They also need to identify and describe process inefficiencies (e.g., manual tasks that could be automated, poor sequencing of tasks etc.). in Question4, students need to explain and justify which approach, whether Business Process Automation, Business Process Improvement or Business Process Re-engineering would provide the best solution for the process inefficiencies identified in Question 3.

Similar to Task1, students are required to simulate an imaginary business scenario in Task 2 using the SIMUL8 software to investigate and improve resource utilization in the case study given (e.g., supply chain network). As part of the coursework assignment, students are provided with personalized data in a spreadsheet indicating supply chain data such as the inter-arrival time, average process time for different work centers and the probability distribution of parts in the supply chain network. Based on the results of the simulation model, students need to interpret the data the simulation runs produce. Students are also required to discuss how confident they are that their results are statistically reliable. Students are given detailed feedback for both coursework assignments indicating their weaknesses, strengths and how they can further improve their modeling and simulation techniques.

Strong written and oral communication skills are vital in the business world especially as a Business Analyst. The communication of results is an important process because if this information is not communicated effectively, clients or other stakeholders may misperceive the assessment results. Accordingly, both coursework assignments must be written in a manner that is understandable to someone unfamiliar with simulation modeling and analysis. The remaining 50% of the final grade is based on a 2-hour unseen exam. Students are assessed formally based on their overall understanding of those 4 broad areas mentioned in section 3.2.2.

4 FINAL YEAR PROJECT

In the third year of undergraduate study, students will begin to address research-level issues in the area of computing for business. All students undertake the Final Year Project (FYP) (October-March) which represents a substantial element of their final degree classification. This project is a 6-month long effort where students execute a project from the proposal stage to the delivery of a prototype. They can choose topics ranging from simulation modeling, human-computer interaction or programming. Those who decide to carry on with a simulation project are offered to attend two simulation workshops across the academic year. The first workshop is held during the first term - end of October - and covers the 'Planning and Conceptualization' of a simulation project. This workshop aims to refresh students' knowledge of simulation modeling (i.e., static and dynamic modeling), give a running start in using the available resources and to allow students to think about the important questions they need to ask themselves before starting a simulation project. Some of these questions that we encourage students to ask themselves are shown in Figure 2.

Figure 2. Sample questions before starting a simulation project.

These questions will help final year students to think critically and make meaningful connections between the content we are presenting and real-world applications. It also helps students to remain focused and consider all the alternatives and risks of their decision before finalizing it as a simulation project. Other topics covered in the first workshop include understanding of well-known methodologies in simulation projects, scope of the model, different levels of abstraction (e.g., model level, entity level and resource level), Simul8 functionalities (e.g., simulation clock, key performance indicators (KPIs), and modularity), data collection process and conceptual validation (e.g., validate with stakeholders). In order to enhance students' problem-solving ability, learning experience and active participation during the workshop, we present a case scenario (e.g., a pizza delivery model) and step-by-step instructions before proceeding to actual implementation. After discussing each section students have about 15 minutes to implement/ adjust the necessary settings. From experience, at the end of the first workshop students usually have a good understanding of how to approach a simulation project.

The second workshop is typically held at the beginning of the second term - end of January - and focuses on 'development and experimentation' of a simulation project. The majority of students who attend this workshop have already created the static model but usually need support to further improve and develop their dynamic models. The standard topics covered in this workshop include inter-arrival times, arrival-rate distributions, labels and work items, routing in and out, resource utilization, warm-up period, comparing AS-IS and TO-BE, KPIs, trial calculator, and result presentation. Similar to the first workshop, students will have a play after each of these simulation functionalities by working on an imaginary case scenario.

Experience from previous years has shown that these workshops made the final year Business Computing students more competent and confident in conducting a simulation project. Over the past few years we have had several students working on simulating complex systems (see Mustafee et al. (2006)) with a view to improve internal processes as well as overall performance of various entities. This year, similarly, we had several students working on complex and diverse discrete-event simulation projects ranging from NHS healthcare pathway, to London's underground travel network, to a blood bank center, to name a few. For instance, one of the students considered simulating the workflow of an elite blood bank in Pakistan. In this case, after the first workshop, a static model of the center's existing workflow was created based on the collected data (i.e., AS-IS static model). Following this, and before the second workshop, a rough simulation design (AS-IS dynamic model) was prepared to represent the current state of the center, highlighting the potential inefficiencies.

After the second workshop, various alternatives scenarios for system improvement were investigated by the student. For each scenario, different key performance indicators of the system, resource utilization metrics, and specific queues were traced to reach the optimal solution. Findings of this project indicated that the proposed changes significantly improved the targeted areas of resource utilization, capacity and turnaround time.

5 CONCLUDING REMARKS

The goal of this paper was to share our experience and provide insight into teaching modeling and simulation to Business Computing students in the department of Computer Science, Brunel University London. In this section, we will briefly highlight the opportunities and challenges we have faced teaching the simulation module.

Looking at the positive side, teaching the Business Analysis and Process Modelling module across two terms has enhanced students' theoretical and practical understanding of the business process modeling containing both static and dynamic modeling. While the lectures cover a range of topics, the integrated examples and case studies provide insights into the vital role of a business analyst in a business process management. Furthermore, learning about static modeling during the first term -which serves as a foundation for dynamic modeling in the second term- will structure and enhance students' logical thinking, and problem-solving skills. Thus far, the feedback we have received from students has been positive and consistently highlights the huge impact it has had on students' professional development. The BC students appreciate the structure of the Business Analysis and Process Modeling module, stating that it has developed their analytical and problem-solving skills. Furthermore, students are usually more interested in dynamic simulation modeling as they can interact with the simulated system in real-time, observe and analyze the immediate effects of changes they make to the system through various scenarios.

Having expressed the opportunities, we should not avoid the current challenges that may impede the achievement of module objectives. The first challenge concerning teaching modeling and simulation is to remind students to understand business scenarios from an analyst perspective and not from a customer viewpoint. This is particularly the case when teaching static modeling as students tend to become distracted quite easily by different scenarios. We have attempted to address this challenge by providing as many real-world scenarios to students as possible.

The second challenge is the time spent by students to build a Discrete Event Simulation (DES) model, as it can be quite time-consuming, even for experts (Tako 2011). Currently, too much attention is often put on learning how to build simulation models rather than on the understanding of system behavior and what simulation can be used for. This limitation has two sides to it. First, this is a limitation based on the students' attention as they spend more than two third of the second term learning about the SIMUL8 software and the required functionalities of a simulation model such as labeling, resource utilization, KPIs and so forth. Accordingly, very little time is spent to learn running systems analysis and management recommendations. Second, this limitation might be the result of the current course layout. Considering the complexity of dynamic modeling, one solution is to restructure the course layout by removing one of the assignments. Taking this approach, students can start dynamic simulation modeling during the first term and will only have one extensive M&S coursework comprising of both static and dynamic modeling.

The third challenge is to teach students how to build a simulation model from a static model. We have noticed this mostly among the 3rd year students working on their final year project. While this approach is similar to process suggested by McKenzie et al. (2015) for completing a project from the proposal stage to the delivery of a prototype, it also poses a number of challenges. For example, students usually think that there should be a one-to-one relationship between the entities/ activities in the static model they have developed using BPMN and the simulation model they want to produce. As a result of this, we have noticed students spend weeks working on details that may not be important for a simulation project. We have attempted to address this challenge by introducing two workshops for students as mentioned previously in section 4.

Lastly, the fourth challenge concerns students who start the third academic year after a year's industry experience on placement. These students tend to be more creative in terms of finding a challenging and practical simulation topic (i.e., real-world issues) as a final year project, but this benefit comes at a cost. We have noticed that these students have usually forgotten most of what they learned about modeling and simulation during the 2nd year. Therefore, there is a need to support these students to ensure they are up to speed with the basics of model development and simulation as the 2-hour simulation workshops may not be sufficient to give them a running start.

Although, the feedback we have received has been mostly positive, we believe by making necessary changes to the course layout we can further improve students' career readiness and increase their motivation to learn. Currently, the module has been designed to serve the needs of our students that is similar the approach suggested by (Mielke et al. 2009). Accordingly, those students wishing to become M&S experts can do so by focusing on mastering the M&S body of knowledge. On the other hand, those students wishing to utilize M&S as a tool can do so with knowledge that they will learn enough about to be competent users. Future studies are therefore needed to evaluate the usefulness of using simulation games for teaching and learning DES simulation for 1st year undergraduate students. This may help to capture the attention of students and encourage them to learn fundamentals of M&S (Padilla et al. 2016).

We hope this paper will be useful to stimulate discussion with regard to teaching model development and simulation in higher education institutions.

REFERENCES

Altiok, T., W. Kelton, P. L'Ecuyer, B. L. Nelson, B. W. Schmeiser, T. J. Schriber, L. W. Schruben, and J. R. Wilson. 2001. "Panel: Academic Perspectives: Various Ways Academics Teach Simulation: Are They All Appropriate?". In *Proceedings of the 2001 Winter Simulation Conference*, edited by B. A. Peters et al., 1580-1591. Piscataway, New Jersey: IEEE.

Banks, J., J. Carson, B. Nelson, and D. Nicol. 2013. *Discrete-Event System Simulation*: Pearson New International Edition (Pearson Education Limited).

Brooks, R. and S. Robinson. 2000. *Simulation Studies: Key Stages and Processes*. Palgrave Macmillan, 2000.

Dahlstrom, M. F. 2014. "Using Narratives and Storytelling to Communicate Science with Nonexpert Audiences." In *Proceedings of the National Academy of Sciences of the United States of America*, 111 Suppl 4(Supplement 4), pp.13614–20. http://www.ncbi.nlm.nih.gov/pubmed/25225368, accessed July 10, 2018.

Dobson, G. and R. Shumsky. 2006. "Web-based Simulations for Teaching Queueing, Little's Law, and Inventory Management". *INFORMS Transactions on Education* 7(1):106–124.

Fousek, J., M. Kuncova and J. Fábry. 2017. "Discrete Event Simulation – Production Model in Simul8". In *Proceedings 31st European Conference on Modelling and Simulation*, edited by Z. Zoltay et al., 229-234.

Garneli, V. and K. Chorianopoulos. 2017. "Programming Video Games and Simulations in Science Education: Exploring Computational Thinking through Code Analysis". *Interactive Learning Environments* 26(3):386-401.

Hlupić, V. and V. Vukšić. 2004. "Business Process Modelling using SIMUL8". *European Simulation Symposium: Simulation in Industry*, 16.

Jacobson, S. H., D. J. Morrice, D. H. Withers, E. Yucesan, and W. D. Kelton. 1994. "Teaching Simulation: A Panel Discussion." In *Proceedings of the 1994 Winter Simulation Conference,* edited by J. D. Tew et al., 1378-1381. Piscataway, New Jersey: IEEE.

Kazimoglu, C., M. Kiernan, L. Bacon, and L. Mackinnon. 2012. "Learning Programming at the Computational Thinking Level via Digital Game-play". In *Procedia Computer Science*, 522-531. Elsevier.

McKenzie, F. D., R. R. Mielke, and J. F. Leathrum. 2015. "A Successful EAC-ABET Accredited Undergraduate Program in Modeling and Simulation Engineering (M&SE)." In *Proceedings of the 2015 Winter Simulation Conference,* edited by L. Yilmaz et al., 3538–3547. Piscataway, New Jersey: IEEE.

Mielke, R. R., M. W. Scerbo, K. T. Gaubatz, and G. S. Watson. 2009. "A Model for Multidisciplinary Graduate Education in Modelling and Simulation". *International Journal of Simulation and Process Modelling* 5(1):3-13.

Mustafee, N., S. J. E. Taylor, K. Katsaliaki, and S. Brailsford. 2006. "Distributed Simulation with COTS Simulation Packages: A Case Study in Health Care Supply Chain Simulation". In *Proceedings of the 2006 Winter Simulation Conference*, edited by L. F. Perrone et al., 1136–1142. Piscataway, New Jersey: IEEE.

Padilla, J. J., C. Lynch, H. Kavak, S. Evett, D. Nelson, C. Carson, and J. del Villar. 2017. "Storytelling and Simulation Creation". In *Proceedings of the 2017 Winter Simulation Conference*, edited by W. K. V. Chan et al., 4288-4299. Piscataway, New Jersey: IEEE.

Padilla, J. J., C. Lynch, S. Diallo, R. Gore, A. Barraco, H. Kavak, and B. Jenkins. 2016. "Using Simulation Games for Teaching and Learning Discrete-event Simulation". In *Proceedings of the 2016 Winter Simulation Conference,* edited by T. M. K.Roeder et al., 3375-3384. Piscataway, New Jersey: IEEE.

Roberts, S., J. Banks, J. Kho, U. Pooch, J. Ramberg. 1982. "Teaching Simulation to Undergraduates." In *Proceedings of the 1982 Winter Simulation Conference*, edited by Highland et al., 706-710. Piscataway, New Jersey: IEEE.

Robinson, S. 2004. *Simulation : The Practice of Model Development and Use*. John Wiley & Sons Ltd.

Saltzman, R. and T. Roeder. 2013. "Perspectives on Teaching Simulation in a College of Business". In *Proceedings of the 2013 Winter Simulation Conference*, edited by R. Pasupthy et al., 3620-3629. Piscataway, New Jersey: IEEE.
Schultz, S. and C. Geiger. 2005. "Transitioning Students from Simulation Mechanics to Simulation as a Process Improvement Tool: A Multimedia Case Study Approach". In *Proceedings of the 2005 Winter Simulation Confeence*, edited by M. E. Kuhl et al., 2314-2321. Piscataway, New Jersey: IEEE.
Smith, J., C. Alexopoulos, S. G. Henderson, and L. Schruben. 2017. "Teaching Undergraduate Simulation - 4 Questions for 4 Experienced Instructors." In *Proceedings of the 2017 Winter Simulation Conference*, edited by W. K. V. Chan et al., 4264-4275. Piscataway, New Jersey: IEEE.
Tako, A. 2011. "Model Development in Discrete-event Simulation: Insights from Six Expert Modelers". In *Poceedings of the 2011 Winter Simulation Conference,* edited by S. Jain et al., 3928-3939. Piscataway, New Jersey: IEEE.
Wing, J. 2006. "Computational Thinking". *Communications of the ACM* 49(3): 33–35.

AUTHOR BIOGRAPHIES

ARMIN KASHEFI is Lecturer in Business Computing in the Department of Computer Science, Brunel University London. He has an MSc and PhD in Information Systems Management. His research interests include people and technology, information systems for crisis response and management (ISCRAM) and information and communication technologies (ICTs) and development. He was recently involved in two EU-sponsored projects (TANDEM and Sci-GaIA) working on developing sustainable e-Infrastructures in the West and Central Africa. His current research continues to explore sustainable e-Infrastructures in Africa as well as modeling and analysis of complex systems using discrete simulation modeling. His email address is: armin.kashefi@brunel.ac.uk.

FARIS ALWZINANI is a Lecturer in the Department of Computer Science at Brunel University London, where he also received his MSc and PhD in Information Systems in 2012 and 2017 respectively. In terms of Teaching, Alwzinani had an experience of 6 years as Lecturer Assistant in a variety of undergraduate and postgraduate modules. In terms of research, he focuses on Busines Computing, Complex Systems, Business Process Modelling and Simulation Methodologies. His email address is: faris.alwzinani@brunel.ac.uk.

DAVID BELL is a Senior Lecturer in the Department of Computer Science at Brunel University London where he carries out research into digital service design – including the simulation of user interactions and behavioral change. Dr. Bell spent 15 years working in the IT industry (primarily within Investment Banking) in roles from developer to technology director. Dr. Bell is the Education Chair for the ACM SIGSIM where he is involved in the promotion and support of doctoral simulation researchers.
His email address is: david.bell@brunel.ac.uk.