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Teaching Service Modelling to a Mixed Class: An Integrated Approach

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Abstract. Service modelling has become an increasingly important area in today's telecommunications and information systems practice. We have adapted a Network Design course in order to teach service modelling to a mixed class of both the telecommunication engineering and information systems backgrounds. An integrated approach engaging mathematics teaching with strategies such as problem-solving, visualization, and the use of examples and simulations, has been developed. From assessment on student learning outcomes, it is indicated that the proposed course delivery approach succeeded in bringing out comparable and satisfactory performance from students of different educational backgrounds.

Keywords: service modelling, queueing theory, mixed-class teaching.

1. Introduction

From the Internet to pervasive mobile computing, the recent decades have witnessed unprecedented, rapid technology evolutions. The fast advance of various technologies, ranging from optical fibre, Wi-Fi, satellites, 3G and 4G, to ultra-wide band, near-field communications, RFID, wireless sensor networks, and cloud computing, poses challenges of many technological dimensions that a telecommunication carrier or an enterprise client needs to cope with. Amid the increasing technical complexity, there is a growing "convergence" of modern information technology and telecommunications, and next-generation networking and computing are becoming more and more service oriented (Price, 2009). Therefore, service engineering has become an important notion that is useful for better design, planning, operation, and maintenance of various ICT services.

Pedagogically, there remains a lack of sufficient attention paid to the service modelling aspect of telecommunication engineering. Traditionally, the teaching of telecommunication engineering has been rather low-level focussed and technology oriented. The fast paces of technological advances in various fronts make it a non-trivial task as technologies get invented, start to evolve, become legacy, and eventually phase out. All these imply that both for telcos and other enterprises there is a wide range of technologies to choose for adoption, to understand, optimize, and plan out against migration and sustainability.

The notion of effective modelling of the communication systems for service performance optimization has been incorporated into the pedagogic agenda (Fitzsimmons and Fitzsimmons, 2006). Mandelbaum and Zeltyn (2010) recently also argued that there is a gap between today's academic supply and the demand for service engineering, and that for building successful systems of the future we must combine technological knowledge with process design.

To respond to the fast rising importance of service modelling and planning in the telecommunications industry, we started to offer a Network Design course in our third-year Telecommunication Programme. It is planned as a capstone course of the Telecommunications curriculum, where technologies were not taught per se, but various modelling and design aspects of telecommunication services are examined, such as the life cycle, systems design principles, performance optimization, functional designs, and technology migrations. A core component of this course is queueing theory.

In light of the ICT convergence, we have then realized that service engineering is also rather relevant to the Information Systems domain despite its weak presence in the IS curriculum design. In 2005 we amended the prerequisite and started to offer the course to students majored in IS. As the new group of students are also familiar with networking technologies, little effort is required in amending the course content. The IS students find the service modelling topics easily applicable in the IS design and maintenance context. Their knowledge of information service management and business communication, usually better than their engineering counterparts, has also been a positive contribution to the class, while the technical know-how of Telecommunications students on various networking technologies becomes complementary. The diversity of the class in fact introduces dynamics in course activities and students benefit from their background differences.

Nevertheless, considerable challenges have been experienced in teaching the course to a combined class. Significant differences exist in students' mathematical background, skills, and their understanding about the business operations within enterprises. Throughout recent years we have developed an integrated approach that facilitates effective mathematical teaching using strategies such as visualization, simulation, and problem solving. It aims to accommodate the students' diversity, allowing them to develop sound knowledge about service modelling and be able to apply this knowledge to solve real-world ICT design problems.

In the remainder of this paper, we will first present in Section 2 a quick review of relevant literature on the teaching of queueing theory and mathematics in general, and on class diversity management. This is followed by an elaboration of class diversity in Section 3. The course syllabus is given in Section 4 and our delivery approach is presented in Section 5. To evaluate how effective the delivery approach is, student assessment results and teaching evaluation results are presented and analyzed in Section 6. Finally we conclude our paper along with some discussion on future work.

2. Related Work

The topic of teaching queueing theory has been widely discussed in the literature. Fitzgerald and Place (1995) explored the use of computer algebra systems (CAS) for teaching queueing theory. Chan (2007) used an inquiry-based approach, where a specific WebQuest platform was employed. This integrated approach includes teaching queueing theory as well as simulation. Garcia and Hernández (2010) employed a number of active learning methods in teaching queueing theory in a one-year span to students majored in Telecommunication Engineering. Mandelbaum and Zeltyn (2010) addressed teaching service engineering, with a queueing theory focus, based on using real-world data collected at an Israeli call centre. Customized databases and statistics tools were employed for online statistical analysis and simulations.

More broadly, the teaching of engineering mathematics in general is a recurring topic in the literature. Various techniques have been proposed, including the use of CAS (Rielly, 2005), animations (Kidron and Zehavi, 2002), and multi-discipline projects (Bischof *et al.*, 2007). Lyons and Beilock (2012) carried out an interesting psychological study on mathematics anxiety, revealing that it is the anticipation of doing mathematics (rather than the process of working on mathematics) that produces anxiety related pains. On the other hand, Thomas *et al.* (2011) looked at the data of university entry scores and engineering students performance, and concluded that the correlations between the two either do not exist or are too weak to base any educational inventions on.

There is a notable widespread bemoaning about the dwindling mathematical standards in today's engineering undergraduates, and various potential solutions are proposed to overcome the limitation of traditional mathematical teaching (Mustoe, 2002; Henderson and Broadbridge, 2007; McCartan *et al.*, 2010; McNeilage, 2014). Assaad and Silva-Martinez (2009) looked at using graphics to enable effective teaching of amplifier design to engineering students with a weak mathematical background. Henderson and Broadbridge (2007) studied measures taken by a number of Australian universities to face this challenge, and noted several common remedies, including promoting short-term bridging courses, moving towards problem-based learning and teaching in context, and employing full-blown first-year engineering programmes.

Handling diversity in class has been discussed widely in language education and child education (Wilkinson, 2012). In the informatics domain, the experience in teaching object-oriented analysis and modelling to classes of mixed students has been reported, where students survey reveals that course delivery should be carried out in different manners regarding to students' different previous knowledge levels (Boberić-Krstićev and Tešendić, 2013). On the postgraduate level, Dowling (2011) explored a number of strategies used to deal with the student diversity and provide flexible teaching and assessment in a distance learning Masters programme.

3. Class Diversity

As mentioned before, considering the growing convergence between IT and telecommunications, we saw an important role that service modelling can play and developed a service modelling course that has since been offered to both IS and Telecommunication (TELE) students.

Through our observation, the diverse class has three groups of different learning styles (Eddy, 1999):

- Auditory learners.
- Visual learners.
- Kinesthetic-tactile learners.

The first group benefit from discussions and excel in presentations; the second learn more quickly from graphs and pictures; and the third are more hands-on, enjoying doing experiments and simulations. The class diversity is also reflected in the following aspects:

- Mathematical background. While some mathematics and statistics courses are compulsory to first-year TELE students, these are optional to IS students. This background difference is caught early on every year when the students need to use formulae to compute queueing performance. Telecommunication students are usually more confident in doing numbers crunching by hand, while some IS students quickly turn to online calculators.
- Programming skills. In terms of programming experience, TELE students have been exposed mainly to low-level, small-scale problem solving tasks, while IS students are more used to large-scale system integration and user interface design, and tend to ignore details.
- Thinking style. There are a group of Engineering students who are used to teachers' feeding them with inputs; and they will then use formulae or tools to work out an answer. However, facing with insufficient information in an assignment (which is intended), they are simply lost and cannot proactively acquire information through interaction and research. IS students seem to deal with such a situation more naturally.

4. Course Information

4.1. *Prerequisite*

The prerequisite is a Network Management course where students get familiar with networking technologies and network configuration. The students background difference is resulted from earlier difference in their pathways: the Telecommunications Engineering students have studied at least one first-year mathematics course (algebra and calculus) besides a physics course, none of which is a requirement for IS students.

4.2. *Resources*

Because of the specially designed course content we cannot find a single textbook that suits our purposes. Selected sections are taken from several books and these are combined with other online readings as the core course material.
We use a course website as the central portal that hosts all teaching materials (including lecture notes, readings, tutorials, laboratory books, and assignments). It also links to a blog site on which we encourage students to post discussions and interesting links they have found relevant to service modelling and telecommunications in general.

To allow the students to conduct performance analysis of complex systems such as *M/M/c* and priority queues, we give out bonus questions (with marks counted to the internal total) for student "volunteers" to contribute Python code, and share the code to the rest of the class along with a homemade spreadsheet. The benefit is two-fold, encouraging more capable students to develop better mathematical understanding while exercising their programming skills, and at the same time providing utilities for students who prefer bypassing the complicated formulae but using tools they feel most comfortable with.

To pair with theoretical queueing analysis, we also adopt the simulation approach. Simulation packages such as OMNeT++ and the Network Simulator (NS-2) have been used in the course. After a few trials we have settled down on NS-2 since it provides easy implementation of abstract queueing model simulations as well as supporting large-scale network simulations with realistic traffic modelling. The detailed animation of packet behaviours in NS-2 is also a useful feature.

4.3. *Assessments*

Assessment plays an important role in student learning. Our assessment package consists of two parts: internal and external, each taking up 50% of the full marks. For internal assessment three assignments are used:

- Assignment 1 is on performance optimization of a networking system using queueing analysis and simulations. Over the years a number of scenarios have been alternately used, including multi-core implementation schemes for network intrusion detection, an enterprise web service with load-balancing requirements, and an image retrieval service where jobs are to be dispatched over multiple servers. There are no obvious right answers to these tasks and the students are encouraged to be critical and think out-of-box.
- Assignment 2 is topology design task that aims at connecting branch offices of a nation-wide company in New Zealand. It requires students to identify potential reliability issues within a network topology, and find efficient solutions within a given budget. It also allows students to exercise their programming skills to simulate real-world network traffic manipulation.
- A network design project that incorporates a larger enterprise networking context, with more service requirements and constraints (such as policies and financial

limits). Realistic settings are given, including technology choices from telecommunication operators, NZ geographical data, and cost models. Some information is left out deliberately, requiring the students to interact with the clients (impersonated by teaching staff) and acquire necessary information via emails. While students need to work out quantitative design details such as link characteristics, system reliability and costs etc., the major design components, including choices on technologies and functional designs, are qualitative by nature.

All internal assessment tasks are presented as realistic problem-solving scenarios in a New Zealand enterprise setting. This requires students to link multiple factors arisen: business goals, locations, user population, budget, technology supportability etc. Student feedback suggests that this enterprise setting has been appealing to them and related to business roles that they intend to undertake in real life.

The final exam consists of basically two parts: short-answer questions for testing on students' understanding of network design methodologies and modelling issues, such as components of queueing systems and their Kendall annotations; long-answer questions are designed for testing on problem-solving. For instance, given an enterprise network and key applications running within the network, the students are asked to choose a queueing model for performance analysis and suggest measures to achieve the best service quality under potential constraints.

As the focus has been on conceptual understanding and application rather than memorization, we list all the queueing model solution formulae on a "cheat sheet" which is provided in addition to the exam questions in the final exam. Calculators are also allowed.

Apart from these major assessment units, there is also a small presentation unit (5%). The class is split into several teams, each taking on a chosen topic. Some relevant, but slightly controversial topics such as "deep packet inspection", "enterprise IT cloudization", and "net neutrality" etc., are given as the options. Presentations are organized as 3-minute debates, with the teams being encouraged to take strong positions (in terms of being affirmative or negative). The students seemed to have enjoyed these debates, and they were motivated to conduct research on the chosen topics. This way they can not only identify and appreciate the technical issues neglected by media coverage, but also capture the social, ethical, and business operational dimensions of service engineering.

5. Teaching and Evaluation Methods

5.1. *General Approach*

We take a problem-solving approach in the delivery of our course, different from the data-oriented approach by Mandelbaum and Zeltyn (2010). Our reasons are two-fold: first, there are many real-world scenarios in telecommunication and information system engineering that require us to use appropriate modelling for performance analysis and optimization; secondly, a problem-based approach allows the students to get engaged early on with problem solving in realistic business environments, where data gathering is a necessary and crucial initial stage.

We do have a problem to solve for course delivery. The queueing theory is the core of the service modelling and it is inherently mathematical. Queueing theory is largely missing in Information Systems curricula. There is a common observation that teaching mathematics to IS students is challenged by students' "maths-phobia" (Harvey and Holdan, 2004). We argue, however, that the lack of mathematical content in the IS curriculum, and the lack of attempts in teaching mathematics in more effective ways, contribute to the aggravation of the problem.

Informed by previous studies (Thomas *et al.*, 2011), we assume despite the weaker mathematical background among IS students, queueing theory can be taught effectively to them. If we deliver the mathematically intense material in a vivid manner assisted by using stories, examples, and animations, and make working with formulae an encouraged rather than an expected activity, potentially the initial anxiety will disappear (Lyons and Beilock, 2012). Rather, some sense of fulfilment may be fostered, once the students become fluent in using spreadsheets and simulations for problem solving. Our intention is to equip both IS and TELE students with the understanding and knowledge about queueing models so that they can use the understanding and skills to optimize the performance of an information system or a telecommunication network. A secondary goal is to develop students' systems view points and their critical thinking ability, so that the problem solving process actually results in some good ideas.

We regard the mathematical presentation necessary. To understand and be able to apply queueing models, of course one needs to capture the main concepts of queueing systems, and be familiar with the Kendall notations. We also need to inform the students about the properties of various probability distributions so that they can understand why different traffic profiles may affect the system performance. More importantly, they will need to learn to match real-world scenarios to an adequate queueing model in Kendal notation, so as to find the right formula (or the right option in a spreadsheet) for problem solving. All these are not possible without an adequate level of exposure to mathematics.

With a combined class of IS and TELE students with different learning styles, we must orchestrate an engaging delivery process. This means rather than teaching on notations and formulae per se, we need to take advantage of a number of learning strategies.

5.2. *Learning Strategies*

To enable mathematically oriented coverage on queuing theory, a couple of bridging lectures are employed to give students a quick, but progressive review of basic concepts such as probability, random distributions, and stochastic processes. This naturally leads to the introduction of birth-death processes, and Markov state transition diagrams. For the rest of the queuing theory, we integrated a number of strategies or "tricks", to enable students' learning of queueing models and their analytical solutions. In light of the class diversity, these tricks are designed to match students' different backgrounds and learning styles.

5.2.1. *Trick 1: Incorporating Visualization*

A picture is worth a thousand words, especially to visual learners (Eddy, 1999). Visualization is employed through out the teaching of queueing theory via the use of diagrams and animations. Sometimes simple diagrams such as Fig. 1 can become instrumental in developing conceptual understanding. The students are encouraged to think about possible variations to this simple queueing scheme and they find that many of these variations will become useful queueing models matched well to real-world scenarios.

State transition diagrams shown in Fig. 2 give another example we have used to visualize mathematical subtleties. The difference of these two diagrams, especially the death rates between system states (lower links pointing left on each diagram) are reflection on the number of servers in a system. The green and blue links in Fig. 2(a) are inflows and outflows for State “2”, and the sum of the rates for inflows and outflows on any state of a stable queueing system should be equal (on which we bring in the analogy of a sink with water flow in and out). We then show that by simple mathematical derivation one can work out the solutions for such a queueing system.

To better explain the derivation of *M/M/c* performance, we use again colour coding (of the background) in the state diagram as shown in Fig. 2(b) to indicate that there are two patterns of the states’ departure rates. Once this visual clue is pointed to students, they can then align the derivation process of *M/M/c* solution with these two different regions.

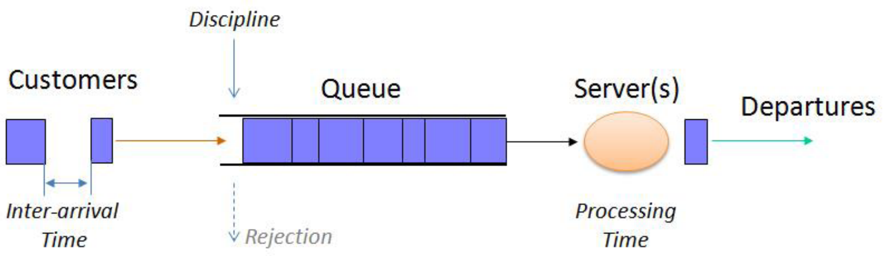
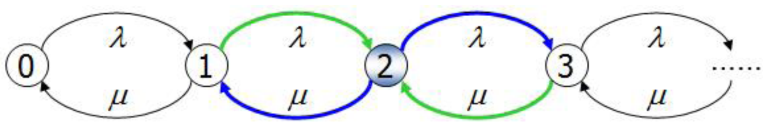
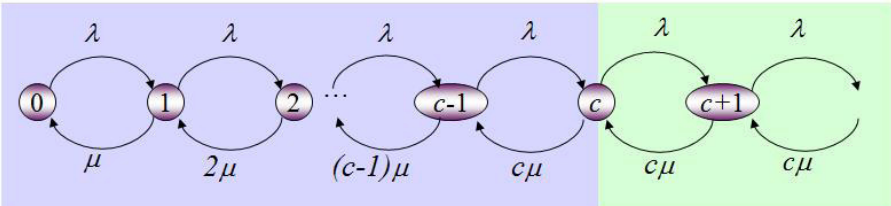


Fig. 1. Diagram of a simple queueing system.



(a) *M/M/1*



(b) *M/M/c*

Fig. 2. Markov chain diagrams used to explain the queueing models of (a) *M/M/1*, and (b) *M/M/c*.

When talking about the self-similarity in the Internet traffic, a more advanced topic in teletraffic analysis, we use fractal images and pictures of fern leaves and Romanesco broccoli to demonstrate the concept of fractals. These beautiful fractal pictures help to stimulate their interests and allow them appreciate the 'self-similarity' concept more vividly. This then leads to a case study of self-similar Ethernet traffic, also visualized by PowerPoint slides for better explanation.

PowerPoint animations and animated computer simulations are also presented in class, which are further assisted by simulation labs, allowing students to visualize the queueing systems and observe their behaviours.

5.2.2. *Trick 2: Using Examples*

While mathematical presentation is necessary in teaching queueing theory, at times it can become too abstract and dry to talk about Kendall notations and the formulae. Fortunately queueing is such an omnipresent phenomenon in real life that it is easy to draw on real-world examples to demonstrate relevant ideas. We make constant references to daily-life situations, such as queues in airports, banks or supermarkets, call-centre services or student canteens etc., and project these to concepts such as priority queueing, multiple queues versus single queue, bursts, and job dispatching strategies.

Another group of examples come from the computer networking domain, where various networking technologies are brought under the light of the queueing modelling, so that the students can see how they can use their conceptual understanding to solve real-world problems inherent in these technologies. This also applies to topology design, where we present the Southern Cross cable system as an example to demonstrate the crucial role of redundant links in achieving carrier-level reliability.

Example queueing problems are given and attempted in lectures and tutorials. Sometimes we even ask student volunteers to come afore to the blackboard and show his/her solutions to the class. The invitation normally will succeed and students get involved and are also encouraged.

By referring to everyday examples and networking implementations, students are also challenged to balance the queueing theory with real-world factors beyond pure engineering considerations. For instance, students are first shown using examples that for pure efficiency a multi-server queue system (modelled as *M/M/c*) is always preferred over a multiple single-server queues system (modelled as *c M/M/1*) (Stallings, 1991). They are then challenged by the question why the latter remains to be frequently used in supermarkets or in web server deployments. These examples serve to clarify the students' understanding about the pros and cons of different models, and they seem to facilitate memorization.

5.2.3. *Trick 3: Simulation*

When we ask students to conduct queueing analysis to derive the performance of system in question, additional tasks of conducting computer simulations are also assigned to them. The motivation is two-fold. First, by coding the simulation they will gain more understanding about the overall system process and its key parameter settings; Secondly, by comparing the theoretical results obtained by queueing theory formulae with performance indicators obtained by the simulation, they will have true appreciation about the stochastic nature of the system, as well as understand the impact of not only the average scenarios, but also that of the worst scenarios which is often the culprit of telecommunication service outage.

Computer simulations have been used in teaching queueing theory (Reed, 1980; Dobson and Shumsky, 2006) and TCP/IP networking (Sarkar, 2006). Packages such as NS-2 and OMNeT^{++} have been used frequently used in computer networking research and teaching (Heidemann *et al.*, 2001; Varga and Hornig, 2008). NS-2 simulations have been used in two ways in our course:

- There are lab tasks where UDP flows are generated to simulate simple queueing models such as *M/M/1*, *M/M/1/k*, *M/D/1*, and *M/G/1*. Through simulation, students can better understand the operations of these models and their difference; they can observe the link queues and possible packet drops, and derive performance metrics by analyzing the simulation trace. They are also asked to work with relevant queueing formulae to derive the theoretical values and compare them with the simulation outcome.
- Simulation tasks are included in assignments where large-scale, realistic traffic flows are generated and handled, which highlight the importance of using simulation for large-scale problem-solving.

Teaching on simulation also serves to another pedagogical purpose. By learning how to write simulations, and the same importantly, analyze simulation outcome, students are equipped with relevant research interests and skills for potential postgraduate study.

6. Results and interpretations

6.1. *Assessment Result Comparison*

To evaluate the effectiveness of our delivery approach, especially how well it addresses the class diversity, first we compare the performance of the two groups of students (IS and TELE) across three assessments: the queueing assignment (‘QT’), the design project (‘Project’), and the final exam (‘Exam’). As mentioned in Section 4.3, the first two have distinctive focuses: QT is a quantitative task that assesses students’ understanding about queueing theory, while the project focuses on large-scale systems planning and contains major qualitative components. We would like to see whether the diversity of students affects their performance in these assessments. To ensure whether there exists any statistical significance in the differences of average marks and the standard deviation of marks of each group, two-tailed T-tests as well as F-tests are carried out. The dataset we used contains records of 73 students, roughly even across two groups: 41 belonging to IS, and 32 to TELE, containing 5 years data till 2012.

The statistics on students’ performance in all three key assessment units are summarized in the bar chart shown in Fig. 3. The average marks (in percentage) are indicated by the bars, with their corresponding standard deviation shown as whiskers.

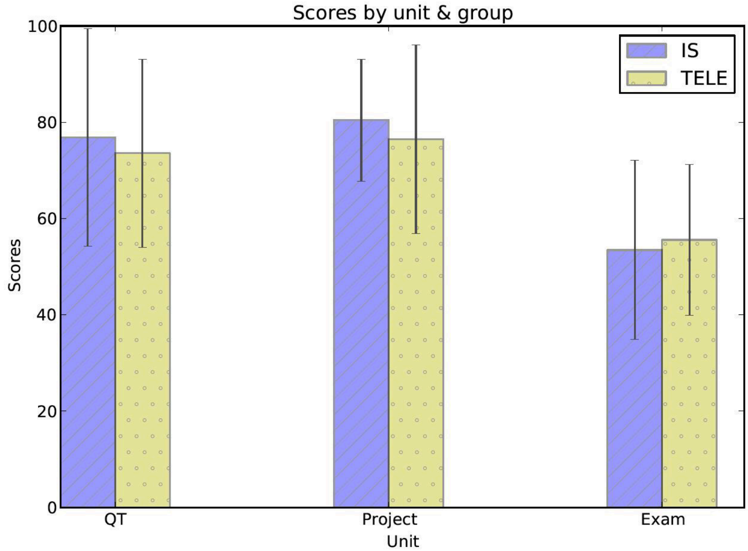


Fig. 3: Assessment result comparison: IS versus TELE.

For the QT unit, contrary to our expectation, the average of IS students is slightly higher than that of TELE group. The statistical difference between the average performance of the two groups is however not significant, as revealed by Table 1.

The performance margin between the two groups becomes enlarged for the project unit. This time the T-test again reports no statistical significance on the average difference, but the much smaller p-value seems to flag a concern. As a consistent tendency observed over the years, it seems the lack of strong communication skills has led to some TELE students being passive and ineffective in project activities such as communication with clients, and reporting. The performance difference between the two groups is reversed in the final exam, where the TELE group scored higher. The average performance however does not bear much statistical significance, as shown in Table 1. We think the stronger problem solving and numerical skills in the TELE group are factors demonstrated in the final exam. Due to the weighting of assessment units, the average final grades of the students from the two groups are almost the same.

On the other hand, the dynamic span of assessment performance, indicated by the standard deviation whiskers, seems to suggest a larger within-group diversity of the IS group than that of the TELE group, especially for the QT and exam units. For the project,

Table 1

Statistical test results on the assessment performance of TELE and IS students.

Assessments	T-Test	F-Test
Queueing	0.518	0.419
Project	0.216	0.596
Exam	0.607	0.334

the opposite is true. The F-test carried out on the difference of standard deviations, as reported in Table 1, however, does not report any statistical significance.

In general, students' performance across different types of assessments reveals that the learning outcome of the two groups has been similar despite their difference in educational backgrounds.

6.2. *Teaching Evaluation Results*

Course evaluations have been conducted several times during the same timespan, and some of the agglomerated results are shown in Table 2. As evaluation questionnaires were returned anonymously, we were not able to tell the identities (and the enrolled programmes) of the students, so the evaluation outcome can only be interpreted on the whole class level. As we can see, all students agreed to that they were challenged to think. The effort they spent in the course seems to correlate well with the class diversity, about 29% of them spending less effort (compared with other courses), while 59% spending more. On the other hand, very positive feedback is obtained on the value of the course, the helpfulness of assessments, and the overall effectiveness of the course delivery.

6.3. *Discussion*

Despite the overall success of the course delivery, we have also identified a few issues. One of these is to do with the handling of subtleties. Given a service modelling problem, the students need to pay attention to some details when characterizing the relevant queueing model. Despite our reiterated emphasis on potential pitfalls in model selection, students fell into them now and then. For instance, only about 20% of students managed to identify a model in a final exam question correctly as *M/D/1*; the others all chose *M/M/1* by mistake.

Most students lacked confidence with their numerical skills and this seems to be a continuing trend. One anecdote was that when it came to translate "a new job arrives every five minutes" into a job arrival rate value, the student started his web browser and visited WolframAlpha to calculate "1/5". This kind of excessive reliance on technology, fortunately, is not a common phenomenon in the class.

Table 2
Teaching evaluation results.

Questions	Feedback		
	Positive	Neutral	Negative
How valuable is the course?	86	14	0
Are you challenger to think?	100	0	0
Do you spend more effort doing this cours?	57	14	29
Are the assessments helpful?	85	15	0
Overall how effective is the cours taught?	93	7	0

Another issue that is under consideration is the use of computer algebra software (CAS). There has been research conducted on using CAS, e.g., Maple, in teaching engineering mathematics and positive outcome has been achieved (Rielly, 2005). There is a concern that CAS, without proper uses designed, operates only as some magic black boxes, hence is not capable of enhancing students learning (Neuper, 2001). So far we have not used any CAS based on two considerations. First, there will be extra overhead introduced by using CAS: we need additional lecturing and lab time to spend on teaching the students how to use CAS. Secondly, even though CAS can be used to help students derive queueing solutions, the latter is not the focus of our teaching goals. Rather, the students are expected to understand the basic mathematical ideas behind various mathematical models (and hence their differences subtle or significant), match real-world networking scenarios with some specific queueing models, and then use tools (either formula or spreadsheets) to calculate the performance metrics.

On the other hand, we also realize that while the current delivery and assessment packages manage to enable students to carry out problem-solving (i.e., to analyze and evaluate) and produce network designs (to “create” to a certain extent), we miss out training their capabilities in using mathematics to model and even find solutions to new queueing systems. It is envisioned that in the future we may offer a few bonus questions and provide CAS tools for students of more mathematics and programming prowess. This would encourage them to develop research interest and skills for future study.

Another interesting idea that is worthy of consideration is a “by projects” approach (Bischof *et al.*, 2007), which might help more self-motivated students identify the gaps in their mathematical skill sets and become self-motivated to learn more and bridge those gaps. In this context, optional projects can be explored, for example, by employing CAS.

7. Conclusion

Teaching mathematical content to students of computing background is always challenging, especially when class diversity exists. In this paper we presented a case study on our effort in delivering a service modelling course to students of Telecommunications and Information Systems majors. Following a problem-based approach in mathematical teaching, we developed a number of learning strategies to assist students learning and these seem to have worked to accommodate the class diversity. Statistical analysis on students performance and teaching evaluation outcome suggest that the delivery has been satisfactory, and comparable learning outcome has been achieved across different student groups.

In the future we will work on further improving our teaching approach. Items on the agenda include reassessing the possible use of CAS and integration of smaller projects that allow more capable students (from both backgrounds) to explore more topics of interests. In a larger background, we believe that it is also relevant for us to reassess the curriculum design for both the engineering and IS degrees. Rather than consolidating the delivery of the service modelling course, some other scaffolding measures may be necessary, for instance, laying out better first-year foundations in mathematics, and training for better communication and interpersonal skills (Hermon *et al.*, 2011). With the arrival of the era of cloud computing and big data, the question remains to be answered – have we done enough to educate the next-generation engineers and developers to face service engineering challenges of the future?

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Paslaugų modeliavimo mokymas skirtingose studijų programose: integralus metodas

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Paslaugų modeliavimo procesas tampa vis svarbesnis šiuolaikinių telekomunikacijų ir informacinių sistemų plėtros darbuose. Siekdami mokyti skirtingų (telekomunikacijų inžinerijos ir informacinių sistemų) studijų programų studentus paslaugų modeliavimo, pritaikėme tinklo projektavimo kursą abiems studijų programoms. Buvo sukurtas integralus metodas, įgalinantis dėstyti matematiką pasitelkus problemų sprendimo, vizualizavimo, pavyzdžių naudojimo ir simuliavimo metodus. Studentų mokymosi rezultatai parodė, kad pasiūlytas kurso pateikimo metodas pateisino lūkesčius ir turėjo teigiamą poveikį studentų rezultatams.