Quality of Service, Quality of Experience and Online Learning

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Abstract— Online learning tools are widely used in engineering education. This includes traditional face-to-face, but also distance education. Since these tools rely on Internet connections, the performance of those connections (speed, latency) can impact on how learning tools are experienced by students. Quality of Service (QoS) describes technical performance parameters that reflect the quality of an Internet connection. Quality of Experience (QoE) on the other hand has been widely used to describe how users experience a particular service. In the context of this work, users are students undertaking learning tasks. While technical literature addresses QoE and educational literature discusses online learning, a gap exists describing the relationship of QoS and the quality of the learning experience. This work uses a mixed methods approach to address the research question: What dimensions of QoE of online learning can be affected by QoS? To answers this question, two groups of students were exposed to changing QoS conditions while they were undertaking an online learning activity using remote access technology. Both technical performance parameters, as well as, the impressions where recorded. Subsequently, a focus group was held to get a better understanding of the students' perception of the relationship between QoS, QoE and online learning tools. It is concluded that QoS factors only have an intermediate impact on the quality of the learning experience of the students. Factors such as course design and pedagogy largely determine the quality of online learning.

Keywords-online learning tools; quality of service, quality of experience; quality of learning experience performance; distance education.

I. INTRODUCTION

Online learning activities are often seen as tools to assist student learning and to improve their engagement. This is of particular relevance for students that are remote from campus such as distance education students. Information and Communication Technology (ICT) is used to provide equitable learning opportunities for those students. Examples include audiovisual lecture recordings but also remote access to software and hardware experiments. As these tools depend on telecommunication infrastructure and the Internet; technical performance depends on Internet access speed, location and network traffic. These technical parameters are generally referred to as Quality of Service (QoS). "QoS is defined as the ability of the network to provide a service at an assured service level" [1, p. 3] and includes performance parameters such as delay, jitter and throughput. These parameters can be measured, but are unable to capture the experience of a system user, e.g. whether the system is suitable to perform a particular learning task.

In recent years, the telecommunication industry has placed a higher focus on the consumer experience and Quality of Experience (QoE) has become a major research area. QoE is frequently used in a technical context and "refer(s) to the overall acceptability of an application or service, as perceived subjectively by the end user" [2, p. 216]; "how satisfied he or she is with a service in terms of, for example, usability, accessibility, retainability and integrity of the service." [1, p. 3]; or "as the basic character or nature of direct personal participation or observation" [3, p. 619]. However, no QoE definition is universally accepted or widely used. The term is also well established in psychology and other disciplines (e.g. [4]), where it has a more general meaning. Much of the educational literature in this area has focused on understanding QoS for online tools without reference to the significance of QoS for QoE of learners. QoE research in the technical domain does not directly apply, as learning is very different from the general consumer experience.

Online learning tools are becoming increasingly prevalent in education. This applies to both, face-to-face as well as distance education. Understanding the impact of technical limitations on learning that is occurring is therefore an important research area. This work takes a step forward from the current focus in educational literature on QoS to QoE. This is only a stepping stone as the ultimate goal is to understand the impact of QoS on learning, and not only on user experience. Understanding factors in online learning that are susceptible to changes in QoS is by its own right relevant and can lead to better online learning environments. Using the work of Mayer [4] and Gilbert, Moreton and Rowley [5], this study has developed a model which maps the factors contributing to the quality of the learning experience in online environments. Using a mixed methods approach, it addresses the research question: What dimensions of QoE of online learning can be affected by QoS?

The remainder of this paper is organised as follows: Section II discusses the general context and the background of this study. Section II introduces the interest in QoS for the quality of the learning experience and provides the framework for this study. Section III outlines the methodology that was used and Section IV highlights initial findings. These are discussed in Section V and implications and further work are outlined in Section VI.

II. CONTEXT AND MOTIVATION

This section provides an introduction into the general context and the motivation for this study, the details do not directly relate to the research question. The University of Southern Queensland and the Faculty of Engineering and Surveying have a distinct student cohort with 76% of students studying in a distance mode, not located on campus. Courses are generally offered in an on-campus and external mode in parallel. Traditionally, print material has been used as means to provide learning materials; today teaching relies heavily on ICT tools and Internet technology. This includes the course management system, a branded Moodle instance as well as electronic lecture recordings. In an attempt to provide equitable learning opportunities, the Faculty of Engineering and Surveying has developed Remote Access Laboratory (RAL) technology [6] that provides external students with access to hardware and software experiments on campus.

The engineering courses that are offered by USQ are accredited by Engineers Australia, the Australian equivalent of ABET. To give students the opportunity to practice practical, hands-on skills, students have to attend practical on-campus sessions, so-called residential schools. During these residential schools, external students travel to Toowoomba to attend a week of laboratory sessions, usually one per semester.

Due to the cliental, the external student cohort is different from the traditional student body seen at many Universities. Most students are mature age and are working full time. The average age depends on discipline and cohorts, but is around 30. Generally they are highly motivated but time poor as they have competing family and work commitments. The quality of the learning experience becomes very important in this environment.

III. THEORETICAL FRAMEWORK

The field of research into online learning is very broad and detailed. Within this body of work, many studies with a technical focus pay particular attention to understanding the effect of QoS on QoE in the learning environment. This focus derives from related studies of QoS in telecommunications or other consumer-based Interactive Multimedia Environments (IMEs). As a result of this heritage, the QoS literature tends to treat users of technology for learning as consumers, with the associated needs and expectations [7]. Where multimedia environments are consumer driven, decades of market driven research into consumer uptake and acceptance of ICTs provides researchers with explicit understandings of what users expect, and how they behave and how they perceive the technology that they are 'consuming.' This 'consumption approach' is demonstrated by [8] who cite various formal and informal definitions of QoE from the available literature which reflect this: "the degree to which a system meets the target user's tacit and explicit expectations for experience"; "subjective measure of a customer's experiences with a

vendor"; "user perceived performance"; and, "the degree of satisfaction of users" (p. 483).

The consumption approach contains a shortfall in attempting to understand how users experience quality in online environments when the task at hand is learning. In attempting to adapt the broader body of knowledge about IME, consumption to environments where users are learners, it is necessary to address the fact that the relevant dimensions that make up QoE are unlikely to be the same. For example, the nature of technology use will be different in terms of users' motivation, their purpose in completing tasks, as well as the nature of the tasks themselves. Each of these variables significantly influences user behavior and perception, and, thus, the nature of QoE. In evaluating the effect of QoS on QoE for learning, it is necessary to specifically consider how system performance issues have affected the learner in the process of carrying out their (learning) tasks. In other words, this requires observing if, rather than assuming that, QoS issues have affected the learning and what the effect has been.

Wu [8] make a significant step in this direction with a shift of focus from a system-centric view of IMEs to a humancentric one, encompassing theoretical frameworks from psychology, cognitive sciences and sociology as well as information technology. They attempt to "map the QoS-QoE relationship" by "capturing the human-centric quality modalities." (p. 481). In doing so, they define QoE as "a multidimensional construct of perceptions and behaviours of a user, which represents his/her emotional, cognitive, and behavioural responses, both subjective and objective, while using [an IME] system" [8, p. 483]. Their model maps the relationships among various QoS and QoE factors drawn from these disciplines. This definition of QoE is useful in that it highlights that QoE must derive firstly from the "user." Experience is necessarily based on perception, which derives partly from the characteristics of the user, but this definition also captures the complex, "multi-dimensional" nature of the environment in which the perception is based. Despite this step forward, Wu et al.'s model does not take a specific focus on experiences in learning environments.

The wide range of available literature on online learning highlights the many course design, learning tool design and pedagogical factors which have a significant influence on quality in online environments [9]. Sambrook's [10] in-depth study demonstrated that many factors, such as userfriendliness, presentation, structure of tasks and navigation within tasks, all affect the perceived quality of online learning tools. Importantly, these are design and pedagogical issues that are central to how the learning takes place. Further, fundamental learning theory holds that factors such as a clear set of instructional goals, the perceived relevance of tasks in relation to these goals and the resultant motivation and cognitive processes of learners, are all central to how learners behave and perform [11]. In this respect, there are influencing factors in online learning environments that are not common to more general online environments. The effect of QoS on how these environments are experienced by users can be expected to be different than for general consumption. To understand the effect of QoS in online learning, it will be necessary to describe how it interacts with these other factors.

In attempting to deal with the issue of perception during learning, Moebs' [12] work focused on the effect of 'flow' (defined as complete immersion within a task, leading to intensive interaction within an activity) on QoE for learners. Flow is directly affected by QoS issues such as access speed and consistency. The detailed QoE model included many factors present in the learning environment which can mediate the relationship between QoE and QoS. These factors include "choice of learning path, learning styles, feedback, interaction" and "clear sets of goals". Despite this, her quantitative method of measuring the effect of flow on QoE did not account for these factors, and consequently, the model is not capable of explaining the relationships among all of the elements that are presented. The author uses a Delphi panel of technical (QoS) experts, rather than an instrument which captures data from the learners or the learning environment. Although flow is expected to be highly relevant to the effect of QoS on QoE, until it is understood how it is mediated by other factors and the learning tasks, the picture is incomplete

IV. METHODOLOGY

A mixed-methods approach has been chosen to capture data about learning from the learners themselves. The study was undertaken in two stages, a pilot study to explore the relevance and coverage of the original model [13] and a main case study to identify dimensions of QoE that are affected by QoS. Initially it was also intended to collect data at the actual student locations via traffic loggers [14]; however, due to unavailability of hardware this was not possible. The methodology, discussed below, was chosen instead.

A. Pilot Study

The purpose of the pilot study was to identify the data that needed to be collected in the main study to address the research question. The pilot consisted of a focus group and a student survey exploring their experience with online learning systems in a third year computing course; and any issues – technical as well as non technical they encountered. The survey questions were based on a comprehensive description of the learning environment by Sambrook [10] as tabled in [13, Table 1]. A focus group session was undertaken to validate the survey instrument and explore the answers in more detail. The pilot highlighted two key issues with implications for the main study [13]:

Students do not have a common understanding of "online learning tools" or "tools for learning". Student perceived many functions of tools of the Learning Management System (LMS) as administrative in nature rather than supporting or promoting learning. The implications of this were that what students perceive as significant for the learning experience may largely depend on how students understand the function of the tools. The pilot also highlighted another issue – the participants focused mainly on issues of course design and delivery when speaking about issues that were significant for their learning. This raises the question if QoS issues can be sufficiently isolated from education design and delivery issues to understand the effect of QoS on QoE. To avoid these issues in the main study, a learning activity in the context of Remote Access Laboratory was used as the learning tool. These activities are perceived by students as sophisticated enough to be understood as a learning tool. Furthermore, variations in QoS such as issues with delay or bandwidth have a direct impact on the performance of the interactive system and help to create a better picture of the impact on QoE. To address the second point and to isolate design and delivery issues from the impact of QoS, students undertook RAL activities that were self-contained and not integrated into a scaffold learning program. Students also undertook the same activity several times, so they were aware of the expected outcomes

B. Main Study

The main case study was based on two groups of students of diversely situated distance students who were on campus for residential school. Due to their mix of near and far, urban and rural locations, these students routinely experienced different QoS in the same academic courses. During their time on campus they were each asked to perform a laboratory experiment, first under normal laboratory conditions and then remotely via computer using RAL technology. During the remote session they were given several attempts at the activity and in each attempt the QoS was varied. Subsequent to the experiment sessions, the students took part in focus groups to explore factors impacting their QoE both for their routine studies, and the test experiments.

To replicate different QoS conditions, a Wide Area Network (WAN) Emulator was used. It is based on NetEm [20] to emulate various network conditions including delay and bandwidth limitations. The emulator was placed in-between the user workstation and the corporate network. Testers configured network conditions with a simple web interface. To make the test environment more accessible to the test subject, network parameters were related to practical access options and locations. The following locations and associated RTT were selected as typical locations for potential system users: Local -Toowoomba (<1ms), Melbourne (50ms), Perth/New Zealand (100ms), Singapore/USA (200ms), Europe/Dubai (300ms) and other locations. These are only indicative values; in practice, RTT largely depends on routes packets take to their destination and routes depends on Internet Service Providers (ISP) and peering arrangements.

The first group of seven students was taking part in a second year hydraulics practice class on campus; a class providing "a broad introduction to the practical aspects of water engineering and focuses on the development of analytical, manual, diagnostic, communication and group interaction skills." The RAL activity was a hardware-based experiment setup of a *tapered passage (Bernoulli)* experiment, where students determine flow rate and pressure heads.

The second group of eleven students was taking part in a third year residential school on operating systems and computer networking. The RAL activity in this example was largely software-based around Ubuntu 9.10, hosted on a virtual machine which can be accessed remotely. The activity includes a shell scripting exercise and control of a web-relay on the

local network. The main aim of this activity is to expose students to shell scripting and the control of a relay via a network connection without the need to install a Linux distribution on their own computers and to purchase the hardware.

Both activities required students to apply theory learned in academic courses to an instance of practice.

V. FINDINGS AND ANALYSIS

This section summarises the outcomes of the student focus groups. All participating students were normally studying by distance education and from different disciplines within engineering. This proved to be an advantage for this study as the students were well practised. This meant that the students were capable of discussing their perception of the QoE of both their general online studies from home and the specific experiments conducted on-campus during residential school. This included being able to report on the specific factors which had an effect on their perception of QoE and what this effect was.

A. Factors Impacting QoE for Routine Studies

The problems that students reported in relation to general online learning included:

- Inconsistent delivery of online courses,
- Disorganised learning environment,
- Learning tools not functioning properly,
- Lack of support from staff,
- Insufficient opportunities to interact with staff and students,
- Inflexible options for how students learn,
- Incomplete materials,
- Lack of pre-existing skills or knowledge.

Predominantly, these problems reflect issues with the design and delivery of courses in the online environment and, consequently, how students are able to engage with online study. This list indicates that participating students were conscious of and thoughtful about their own perceptions and experience of the learning environment, and that they understood how these problems affected the quality of their learning.

The focus groups showed that participants often understood such problems well enough that they could make practical suggestions for how they could be addressed. For example, they suggested lecturers could provide last year's recordings of lectures as a backup for when a recorded lecture was unavailable, or provide amendment pages to study guides to address gaps and errors in these materials, without the need to rewrite. Further, alongside these suggestions they could comment explicitly on how such improvements would reduce their frustration and make achieving their learning tasks easier. Significantly, these students showed remarkable awareness of the realities and difficulties of designing and delivering teaching and learning, including the difficulties for time poor academic staff and equity issues for online versus on-campus students. These observations do not directly relate to the research question, but document the unintended outcomes of this study. This degree of awareness and concern also suggests that the picture of QoE which emerges from their accounts can be considered as thorough, thoughtful and detailed.

B. Factors Impacting QoE for the Test Experiments

In commenting on the specific RAL sessions in which QoS was intentionally varied, participating students showed equal awareness of the environment and their perceptions and experiences of the learning. In addition to the remarks above, the students made two specific comments in regards to the RAL experiments:

- Lag time in the system,
- Lack of feedback from the system.

Lag time relates to poor network performance or QoS; and resulted in increased frustration and difficulty of the task. Students "don't know if they have made an error or if the program is just not working." This sometimes prompted students to go back and check over their work. In both cases, the feedback the systems are able to provide is limited and the lack of feedback from the system makes mistakes or problems hard to identify and resolve.

This is particularly true for students that are not sure about the experiments. Students reported a reduced confidence in their knowledge of the task, and an increased level of frustration when dealing with problems. A reduced sense of achievability is associated with not being able to identify what a problem is, or how to solve it. In the RAL experiments, instances of poor QoS had a clear effect on how students experienced the task. However, despite increasing the difficulty and frustration involved, it also had the positive effect of prompting students to review their work and spend more time ensuring they had completed it correctly.

A more significant problem that students encountered in the experiment was that the design of the RAL activity gave them insufficient feedback on their progress, whether QoS was poor or not. If this was not an issue their overall frustration and difficulty may have been lower. In one instance in the water experiment, a student could not commence the activity because the system did not give him the information that the experiment was not prepared properly. He lost his scheduled session and had to simply try again another day. In a proximal experiment, the nature of the problem would be immediately evident as the student could do a visual check of the apparatus in order to identify what was wrong.

In discussing their problems with online learning and how they dealt with them, the participating students demonstrated a high degree of persistence and motivation. They discussed the enjoyment of learning in their chosen fields, despite the difficulties and frustrations they regularly encountered. Across the board, all reports were that they were time poor, with work and family obligations competing with the demands of study. It was in this light that the significance of the problems they were dealing with emerged. For every instance of frustration and unnecessary time taken to complete a study task, it was their professional or personal life which was impacted. Ironically, participants implied that it was because of their jobs or family commitments that they had opted to study online, and that oncampus learning was not an option, despite being viewed as preferable.

In analysing the overall picture of students' comments on their experience, distinct categories of factors which make up QoE emerged. These are summarised in Table I. The factors are largely expected and supported by the literature. The interesting result is that only Frustration, Achievability, Flow and Extra Time are affected by poor performance; and only if there is an impact on the functionality of the online learning tool, the impact of QoS on Consistency and Quality of learning materials can be avoided.

Factors Affecting QoE for Online Learning	Relevance of QoS
Satisfaction Level of satisfaction experienced upon completing the learning	Not relevant
Frustration Level of frustration experienced in completing the learning task	Relevant only if reduced functionality of tool/program due to reduced QoS disrupts the processes involved in the learning task
Achievability Sense of achievability of completing the learning task	Relevant only if reduced functionality of tool/program due to reduced QoS disrupts the student's ability to complete the learning task
Consistency Consistency of the overall learning environment (e.g. consistent provision, layout and design of tools, materials and activities)	Not relevant
Quality Quality of learning materials provided (e.g. clarity of recorded lectures, currency and relevance of study guides)	Not relevant
Flow Sense of flow when undertaking a learning task (e.g level of interruption to concentration on the task or process due to missing information, poor functionality of tools)	Relevant only if reduced functionality of tool/program due to reduced QoS significantly interrupts the sense of flow of the learning task
Extra Time The amount of time over and above what would required for achieving the relevant learning goal or completing the task if learning was not online (e.g. face to face/on-campus, or in print mode)	Relevant if functionality of the tool or learning environment is affected by poor QoS

For example students reported being frustrated while undertaking activities with low QoS; however, they also reported that this did not impact on the level of satisfaction they felt once the activity was successfully completed. Students in the study also reported that the factors with a positive influence on OoE included a sense of satisfaction from completing a task and the perception that a task was going to be achievable. Detracting from QoE were a variety of problems, primarily deriving from the design or delivery of the online courses, including the quality of tools and materials used for learning. These problems include lack of consistency in how tools are designed and provided, inadequate functionality of tools for the task at hand, lack of support at the times students need it and poor quality and irregular provision of course materials or resources. Poor QoS was only reported as significant in relation to these wider problems or where wider problems were present. Students reported that experiencing any or all of these issues increased the time it took them to complete a task, the level of frustration they experienced during learning, and interrupted their preferred learning processes. Where these problems occurred concurrently, the quality of the students' learning experience was extremely low. Although QoS was sometimes mentioned in reference to these wider issues, in speaking about the factors associated with QoE, students were much more concerned with the design and delivery issues associated with their online coursework.

VI. DISCUSSIONS

These findings suggest that QoS only acts as an intermediary factor between quality of design and delivery of the course and the students' QoE. Given this and the students' overwhelming awareness and concern with the factors which impact design and delivery, pursuing a better QoS in online environments is not likely to have a significant effect on optimizing online learning. The fundamental design and delivery of a course, and students' characteristics and learning processes are much more significant in determining what goes on in the learning environment, how it is experienced, and the outcomes that result. The amount of feedback the students received from the system is also crucial as it allows students to assess their progress. The participants in this study were notably persistent and motivated in pursuing their online learning. They were all relatively competent and confident in using ICTs and operating in the online environment. They were also all studying within the field of Engineering. However, these characteristics are expected to amplify rather than detract from the findings of the project. This is because this cohort's persistence and ingenuity in pursuing solutions and the thought that they gave to understanding their experiences revealed more about the online learning environment than if they had displayed a tendency to simply give up in the face of difficulty. It is reasonable to expect that a different cohort of students, studying in different courses and disciplines would present an entirely different set of learner characteristics and learning processes. However, the problems they would be likely to encounter in the online learning environment may very well be similar or the same, deriving from the same causes. This supposition is borne out by much of the available literature on best-practice in course design, pedagogy and online learning. For example, it is known from an abundance of studies that online learning is optimal when it is interactive, supported and collaborative. It is also well known in general learning theory that making learning more flexible is a reliable means of improving learning outcomes. The assertions made here would be testable in further studies into design and delivery and QoE for online learning.

VII. IMPLICATIONS AND FURTHER WORK

The observations in the study allow for broader conclusions about the importance of QoS to the QoE of learners. The main results of this study suggest that QoE of well designed online courses is only degraded if bad QoS means that the learning activity is no longer usable. This indicates that a QoS threshold exist which is also supported by [15]. If QoS is above the threshold, the QoE is good for well designed and supported activities, if it is below the threshold the learning activity is no longer possible and this impacts on the learning experience. For badly designed learning activities, QoE will be low, independent of QoS. As long as a learning activity is readily usable, improving QoS has little impact on the QoE. For these reasons great attention should be paid to the quality of design and delivery of online learning tools and courses. To achieve high QoE, well integrated and scaffold learning experiences are more important than high QoS, e.g. fast Internet access. Specific aspects of these assertions can be tested in future studies. The natural step to continue this work is to move from assessing the perception of students of the learning experience to assessing learning itself. This is an interesting, but difficult investigation. Assessing learning on a large scale while adjusting QoS is problematic. Another direction for future work is to research how the perception of QoE itself influences learning.

The study also led to the unintended positive insight that students can be an important source to improve course design and delivery. This opens up an interesting new research direction: Much has been written about student evaluations, but very limited work exists that has explored students as a source of pedagogic knowledge and the use of student expertise to improves learning and teaching.

VIII. CONCLUSIONS

This paper has discussed the relationship of QoS and QoE in the context of online learning and was able to address the research question of which dimensions of QoE are affected by QoS? Students reported that the factors with a positive influence on the quality of the learning experience included a sense of satisfaction from completing a task and the perception that a task was going to be achievable. Detracting from QoE were a variety of problems created by the learning environment; the online tools, materials themselves or the online course design. QoS was only reported as an issue where these problems were also present. If these problems increased the time required to complete a task, the level of frustration experienced during learning, and interruptions the students' preferred learning processes were evident. Where these problems occurred concurrently, the quality of the students' learning experience was extremely low. These findings suggest that the influence of QoS is less significant than course design and pedagogical concerns in determining QoE in online learning. This is significant since online learning is often regarded as a means to providing more equitable opportunities for learners that do not have the option of undertaking study in face-to-face modes. Despite this, the project found a number of circumstances in which online students were specifically and significantly disadvantaged compared to on-campus students, for example in opportunities for discussion with peers and teachers, and in accessing incidental and extra materials and information from course staff.

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