Topic: Tools 2 – Chair: James Pellegrino

Quality of experience of online learning tools

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***Abstract**: Online learning tools have become important components of teaching and course delivery. This paper discusses the issues surrounding research into Quality of Experience (QoE) for online learning tools and how it relates to technical performance, Quality of Service (QoS). The relationship between QoE and QoS for online learning tools is often considered important for describing the optimal conditions for online learning environments. Such research largely ignores the vital issue of how learners differ from consumers in their use of information and communication technologies such as interactive multimedia environments. The implication of this difference for understanding technology use for learning is presented and the need for an empirical study to address this is argued for. A pilot was undertaken to further define the methodological requirements of conducting a study into the impact of system performance on QoE. The findings of the pilot study describe issues and implications for designing a research methodology which can begin the process of mapping the QoE to QoS relationship for online learning.*

Introduction

Online learning activities are widely advocated as tools to enhance student engagement and assist their learning journey (e.g., Herrington, Oliver, & Reeves, 2003). In particular, modern distance education uses Information and Communication Technology (ICT) in an attempt to provide students with equitable learning experiences in online environments, when proximal learning is not available. Learning aids span a variety of applications from lecture recordings to remote access technologies. Remote Access Laboratories (RAL), for example, widely discussed in engineering disciplines, allow students to use software and hardware remotely (e.g., Kist & Gibbings, 2010). As online learning systems use telecommunication infrastructure and the Internet, system performance depends on access speed, geographical location as well as network conditions, e.g. traffic.

There has been much work in telecommunications research on capturing the performance of applications that rely on networks from a technical as well as from a consumer perspective. The former are identified by the term Quantity of Service (QoS), the latter by the term Quality of Experience (QoE). “QoS is defined as the ability of the network to provide a service at an assured service level” (Soldani, Li, & Cuny, 2006). Technical performance parameters that relate to QoS, such as delay, jitter and throughput, are relatively easy to measure; however, they say little about the experience of a user or if the system was fit for a purpose.

The term QoE as it is frequently used in a technical context "refer(s) to the overall acceptability of an application or service, as perceived subjectively by the end user"' (Kuipers, Kooij, De Vleeschauwer, & Brunnström, 2010); "how satisfied he or she is with a service in terms of, for example, usability, accessibility, retainability and integrity of the service." (Soldani, et al., 2006); or "as the basic character or nature of direct personal participation or observation" (Kilkki, 2008). However, no QoE definition is universally accepted or widely used. The term is also well established in psychology and other disciplines (e.g., Harman 1990) where it has a more general meaning. In the context of this project, the most suitable definition is based on Brooks and Hestnes (2010) and extended by linking experience to a task, i.e. *"QoE is a measure of user performance based on objective and subjective psychological measures using a service or product"[p12] to achieve a particular task or objective.*

QoE of students in learning environments, however, does not directly fit this definition as it implies the quality of a learning experience. Overall, this study investigates quality requirements to achieve good learning outcomes for distance students using online learning systems in the broadest terms. A key focus of the research project is the highly interactive Remote Access Laboratory. This paper focuses on the effects of system performance on the Quality of Experience of learners. The remainder of this paper introduces context and related work, theoretical framework and the pilot study. Implications for the main study and future work conclude the discussions.

Context – QoS, QoE and Quality of Learning Experience

Much of the attention to Quality of Service for online learning environments derives from related studies of QoS in telecommunications or other consumer-based Interactive Multimedia Environments (IMEs). As such, most of the literature which attempts to account for the effect of QoS on QoE in learning is geared towards the users of technology as *consumers*, with well defined and well understood needs and expectations (including Moller, Engelbrecht, Kunhel, Wechsund, Weiss (2009) and others). Where multimedia environments are consumer driven, decades of market driven research into consumer uptake and acceptance of ICTs provides both explicit and cumulative understandings of what users expect, and how they behave and how they perceive the technology that they are „consuming."

In attempting to adapt such a body of knowledge to understanding the use of technology in learning environments, where users are *learners*, relevant dimensions affecting Quality of Experience may not be the same. Operating as if they were is an assumption that requires testing. For example, technology use should be expected to be different for learning in terms of users" motivation, their purpose in completing tasks, as well as the nature of the tasks themselves. Each of these variables has the potential to significantly influence user behavior and perception, and, thus, the nature of quality of experience. In evaluating the effect of quality of service on quality of experience of online tools for learning, it is therefore necessary to gather data which has the capacity to reveal how system performance issues have affected the learner in the process of carrying out their tasks. In other words, this involves measuring if QoS issues have affected the learning and what the effect has been.

Wu et al. (2009) make a significant step in this direction with a shift of focus from a system-centric view of interactive multimedia environments to a human-centric 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 quality of experience as "a multi-dimensional 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" (Wu et al, 2009, p. 483). Their model maps the relationships among various QoS and QoE factors.

Despite this step forward, this model does not take a specific focus on tasks or learning environments. It is known from the wide range of available literature on online learning that there are many course design, learning tool design and pedagogical factors which have a significant influence on the way that learning takes place in online environments (Mayer, 2003). Sambrook‟s (2001) in-depth study demonstrated that many factors, such as user-friendliness, presentation, structure of tasks and navigation within tasks, all affect the quality of online learning tools. These are design and pedagogical issues which determine how the learner experiences the online environment. At an even more basic level, ubiquitous in much educational literature is the basic premise that things like 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 fundamental to how learners behave and perform (Killen, 2007, Department of Education, 2002). In this respect, there are factors relevant for learners using interactive multimedia environments that are not common to more general consumers of IMEs.

In attempting to deal with such issues, Moebs‟ (2008)‟ work focussed on the effect of „flow‟ (defined as complete immersion within a task, leading to intensive interaction within an activity) on QoE for learners, flow being directly affected by QoS issues such as access speed and consistency. Her detailed QoE model included many factors present in the learning environment which can mediate the relationship between QoE and system performance. 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.

Whilst the qualitative tool used in Moeb‟s study purported to investigate "how important to flow [these pedagogical] factors are," this was done using a Delphi panel of technical experts, rather than an instrument which captures data from the learners or learning environment, or even educational or pedagogical experts. As such, her study does not account for the relative effect of all the factors that are expected to impact on QoE for learning. Although flow is expected to be highly relevant to the effect of system performance (QoS) on QoE, until it is understood how this is mediated by other factors and the ultimate performance of learning tasks, the picture of the QoS to QoE relationship is incomplete.

Theoretical Framework – Dimensions of QoE and their Effect

The present study attempts to address the gap in the current body of work with a mixed-method approach to capturing data about learning from the learning environment itself. It will attempt to answer the question *"What dimensions of quality of experience (QoE) of online learning can be affected by QoS, and how?"* Ultimately, ten participants will be used in a case study which attempts to map the relationship between QoE and QoS for their online learning environments. It is expected that this case study will have the potential provide the basis for future research in which the emergent model can be tested for reliability and relevance across various contexts.

Figure 1 depicts the framework that is proposed as a basis for evaluation of the above research question. It is based on the work of (Mayer, 1989) which proposes the overall cycle and components of the teaching and learning process, and Gilbert, Moreton and Rowley (2007), who demonstrated that aspects of technical performance of online tools can impact on students‟ perception of quality of online learning. By investigating each of these components together, a theoretical map of the relationship between QoS and QoE, including the effect of the mediating factors between them, can be proposed. This study will test this construct via as student surveys and focus groups; as well as providing a more detailed view of the components presented.

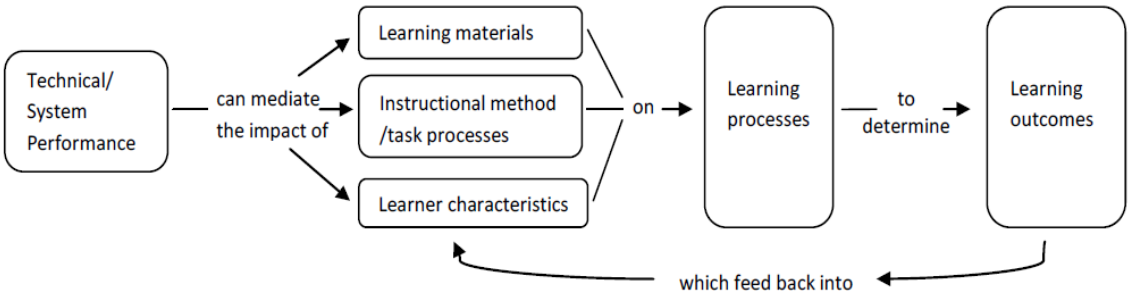

Figure 1: The mediating effect of quality of service on the learning cycle

Methodology – The Pilot Instrument

A pilot study was conducted in order to explore the relevant factors discussed above, and to further define the requisite methodology for the main study. Whist it did not have the capacity in itself to demonstrate the relationships proposed in Figure 1, it was intended as a means of further defining the data needed in the main study in order to be able to do so. The pilot took the form of a focus group and survey of students, asking about their experiences with online learning in a particular course, and any issues (technical or otherwise) which they may have experienced.

Table 2 describes the dimensions and factors that are relevant to quality in learning environments as described by the work of Sambrook (2001). This comprehensive description of the learning environment formed the basis of the range of questions in the survey, so that the instrument would have the capacity to capture data about any or all of these relevant dimensions. This was especially important given that the factors affecting quality of experience for learners in particular are not known.

In combination with conducting this survey, a focus group session was carried out with the same student participants, in order to explore their answers to the survey, and how the survey instrument itself was understood. The constant comparative method was used to analyse the focus group transcripts.

Table 1: Factors comprising the relevant aspects determining success in online learning according to Sambrook (2001)

Learner Characteristics	Instructional Objectives	Task Processes/ Instructional Methods
Experience online, with ICTs and with online learning tools	The link between the theory and application of what is being learned	The learning path (sequence, e.g. open or linear)
Demographics (age, gender, location, access to quality internet connection)	The currency of materials and their application	Task requirements (e.g. processes to be performed)
Attitudes to the course and learning in general	The relevance and coherence of materials and tools and their application	Access to and usability of tools required for task completion
Prior experience and capacity with learning in the relevant subject area	The objectives of specific tasks	The ease of interpretation of task requirements

Findings – Implications for the Main Study

The pilot raised a number of empirical issues for the main study. First, it became clear that a common understanding of what constitutes a "tool for learning" cannot be assumed, and, therefore, the main study has to take a targeted focus on specific activities within the online learning environment to ensure validity. Participating students indicated that they tended to view learning as the acquisition and mastery of content knowledge and therefore saw learning activities as those tasks which were involved with achieving this. This significantly reduced the number of "tools" which they saw as being central to learning in the course they were participating in. It also influenced how they perceived the function of ICTs which were available to them in the course of their learning.

ICT tools such as the discussion forums for the course and the course web page in general were seen as having an administrative function only, rather than one of supporting and promoting the learning itself. It can be assumed that this results, at least partly, from the design of the course in which they were participating – the focus of which was content acquisition, rather than, for example, the application of theory to practice. However, this raises an implication which is independent of course context: *Which online learning tools learner perceives as significant for their experience may depend largely on how they understand the function of the tool that they are using*. If the relevant tool is not perceived as being central to the learning task, the role of the user in cannot be understood as purely that of a learner. This is a potential confound in describing the QoS to QoE relationship for learning.

This finding strongly suggests that the selection of a specific, central and relevant tool would yield the most significant data in the main study for answering the current research question. The clearest opportunity for this is in evaluating the use of a Remote Access Lab tool in which students conduct specific activities that are explicitly central to their learning. This RAL tool is sufficiently sophisticated to be understood by the students as a tool for learning, rather than just an administrative aid. Students see the link between experiment and theory.

It requires learners to perform more complicated learning processes than simple memorization of content, such as the application of theoretical concepts to instances of practice. As such, participants using this tool can be expected to more clearly understand the centrality of the tool to the learning task. This should act to avoid the potential confound that was raised by the pilot study. Further, the use of the RAL tool by learners is more likely to be susceptible to discernable quality of service issues such as speed or consistency of access, than ubiquitous tools such as forums or podcasts, creating a clearer picture of the impact on QoE. The second implication that arose from the pilot derived from the fact that the participants chose to focus mainly on course design and delivery factors when speaking about issues that were significant for their learning. They did not have many significant issues to report that could be said to derive from the quality of service of their online tools. Whilst the pilot did not have the capacity to reveal the reasons behind this, this does highlight a fundamental question for the main study to explore: *Can the effect of quality of service issues be sufficiently isolated from educational design considerations to understand the effect of QoS on quality of experience?* It is possible that quality of service may not emerge as a significant determinant of the perceived quality of learning experiences compared to other factors in the learning environment.

Future Work – The Main Study

Participants in the main study will be situated in a variety of locations expected to produce a variety of QoS parameters. Each participant will be sent an inline network traffic monitor to capture quantitative data about the quality of service of their online learning tools in discrete learning sessions. These parameters include access bandwidth ("speed") of the Internet access; Round Trip Time (RRT) to the university server ("delay") determined by the geographical location and Internet service provider; consistency of service; as well as network traffic information for the duration of the experiment. The learning sessions that are monitored will form part of participants‟ normal course work. As such, the learning activities being studied will be sufficiently contextualised and relevant to the students to ensure theoretical validity. The inline traffic monitor will have no impact on the learning itself, as it will not intrude on the learner‟s perception of the learning environment.

After completing monitored sessions, participants will also fill in a log of any issues they encounter. This will capture their perspectives on what any issues were, their cause, how they affected the learning, and what the student did in order to deal with them. This data will be compared to the network traffic data to uncover patterns between technical performance and learner behaviours and perspectives. It is expected that the data will reveal whether there are any consistent patterns linking QoS to QoE, as well as the effect on and of other mediating factors that are present in the learning environment. The use of these instruments together has the potential to isolate which performance issues were significant in what ways and what their impact was for learning. For example, there may be a close correlation between system events and learner reported issues, or a significant divergence. Either of these outcome has can generate significant findings about the research question, as either scenario can give a strong indication of the importance of QoS in online learning environments.

In line with best practice in diary studies (Bernard, 2006), students who have kept logs will be asked to do a telephone debrief to clarify the data they have recorded. This will allow the researchers to follow up on and triangulate the data from the first two instruments. For example, if there is an event reported in the log instrument which raises questions when compared to the monitor data, this can be investigated by asking targeted questions about the event. Furthermore, the significance of the events for the participants can be clarified. This adds validity to the methodology employed. Even as a case study, the methodological framework being employed demonstrates sound theoretical validity (Yin, 2009), by allowing for all of the factors that impact on quality of experience in learning to be captured in the data.

Conclusion

This paper discussed the outcomes of a pilot study that explores relevant factor that impact on the performance of online learning systems. Key outcomes of this investigation include that students do not necessarily identify learning tools as such and this might impact on their quality perception. The development of the research methodology and analysis of the pilot study have highlighted some significant issues for the field of research which the main study will attempt to pursue and address. The main study will be undertaken in the second half of 2011. Until the significance of quality of service for online learning environments is explored, it is unknown how the existing literature on quality of service can inform the design of effective online learning environments. It is vital that the above issues be explored and understood if further research into quality of service for online learning is to be fruitful. Results will remain relevant as the use of multimedia and other learning technologies will continue to increase in the foreseeable future.

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Acknowledgements

This work has been funded by a USQ Senior Learning and Teaching Fellowship. The authors would like to thank Lesley Jolly, Strategic Partnerships, for their assistance with the evaluation of the quality of experience aspect of this study.

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