DIAGNOSTIC LEARNING: USING WEB-BASED SELF-DIAGNOSTIC TOOLS FOR LEARNING ABSTRACT CONCEPTS IN DATA NETWORK EDUCATION

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Abstract

Subjects such as data networking rely heavily on a 'building block' approach – deep understanding of the simpler concepts are essential if the learner is to be able to appreciate the more complex and abstract concepts upon which data communication protocols are built. For this reason, students' levels of anxiety could increase if the earlier concepts are not grasped adequately – thereby discouraging future engagement with the subject.

This paper describes the historical background to teaching data networks, including feedback and reflection opportunities provided to students via a suite of dynamic, web-based tutorials in a QUT subject. These tutorials utilise context sensitive help screens to aid students' self-diagnosis of their understanding of the subject material. It reports a preliminary investigation into (i) variation in students' learning of abstract concepts (Ii) what strategies are employed by learners in their effective use of a formative web-based tutorial, (Ii) variation in learning outcomes from use of the tutorial. The results indicate that students focus on the parts of networks, and not the holistic picture. They also do not focus on how the network functions. We suggest that these results indicate that new ways of using technology in learning should be pursued as well as a deeper understanding of students' learning outcomes.

Keywords

Abstract concepts, students' perceptions, formative assessment, feedback, reflection, data communications teaching and learning.

Introduction

The learning of abstract concepts is difficult for many. Educators have used a variety of methods to describe and explain these concepts to students with varying degrees of success. Examples of some of these methods include using analogies (Duit et al. 2001; Mulhall et al. 2001; Harrison and Treagust 1993) and animations (Mester and Krumm 2000; Leung and Pilgrim 1995). Although many methods have been tried to teach these concepts, there are few questions that remain to be answered. How well do learners grasp these concepts and also how will learners also know if they have sufficiently grasped these concepts?

Summative assessments have long been used by academics to determine if students have gained an understanding of the subject material. However constant use of assessments can detract from learning due to the pressure exerted on them to perform well in these tasks. From the author's experience, constant use of assessments can also discourage students from the entire unit if they do not do well in them. Indeed Ramsden (1997) reported that overloading students with inappropriate assessments may force students into a situation where they rote learn in order to pass their assessment items. McMahon (1999) also reported that assessments can have the negative effect of encouraging students to concentrate on assessment itself instead of critical thinking.

Formative assessment is another method in which learners are given instant feedback to check on the progress of their learning. This would allow them to perform self-assessable tasks on concepts which they are trying to learn. We will call one of these techniques diagnostic learning. What do we mean by diagnostic learning? To diagnose is to critically analyse the nature of things. Diagnostic learning is the ability to critically analyse one's learning and understanding of the subject material. Hence we can create non-assessable tasks for learners to perform so that they can determine if they have understood concepts within the subject material. To ensure that students do perform these tasks, they can be made to be linked to other assessments in the unit. Blayney (2004) reported that there was a positive outcome to using automated formative feedback in his assessments. However, several authors have reported that the impact on these kinds of assessment opportunities may not correlate with student learning (Peat and Franklin 2003; Peat et al. 2004)

This paper outlines the background to teaching and learning data networks and reports a preliminary investigation into students using the self-diagnostic web-based tutorials for learning about networking in the ITN 667 – Internet Protocol and Services subject at QUT. The paper seeks to inform on the strategies employed by learners in their use of the web-based tutorials. Variation in how students understand the concepts of data network and how they work will also be discussed.

Teaching and Learning Approaches to Data Network Education

Data communication is a highly abstract subject due to the way in which the communication protocols are built. Data communication protocols are processes in which digital data is transmitted over the electronic medium. The protocols describe how data is handled between the end hosts and any intermediate nodes so that data transmission between entities on the network can be achieved. The dominant paradigm for teaching data communications protocols today is the Open System Interconnection (OSI) model. The OSI model describes in detail how data needs to be handle by modular entities within the data communications protocol stack, called layers. Each layer has functions to perform to ensure the proper delivery of data can occur. Most modern data communications textbooks today use this model as their dominant teaching paradigm.

Although the OSI model is the dominant paradigm in the teaching of data communications, in practice no large scale enterprise network implementation of the OSI model has been built. The Internet which is the largest network on the planet today implements the Transmission Control Protocol / Internet

Protocol (TCP/IP) as its communications protocol. Although there are operational similarities between the OSI and TCP/IP Models, there are also enough differences to confuse the novice learner to the area. Many of the major textbooks written to teach data communication have been written around the OSI abstract model.

Suffice to say, due to the highly abstract nature of the communications protocols, the operations between the layers of any data communication protocols can be difficult to explain and describe. Many methods have been used in the past to engage the student in this area including using analogies to describe the processes, kinaesthetic activities and visualisations through complex animations. There are however pitfalls in using some of these techniques which include the misleading the learner (Duit et al., 2001). Novice learners also need a lot of imagination to understand the flow of data between the entities of a network, and if they are misguided in the first place, then the rest of their learning will be flawed. Such flaws may be resilient and be propagated into more advanced years of study. The effect of this propagation will no doubt be detrimental to the future understandings of materials to be learnt (Alexander, 2005).

In an attempt to "visually" show learners how data "moves" within the layers, there have been attempts to build visual animations of the concepts to be described (Leung and Pilgrim, 1995; Derrick and Fincher, 2000; Jard and Jèron, 2000) . However, as reported by Dowling et al (2005) these animations may have limited success if they do not actively engage the learner. To compound the difficulty encountered by novice learners to the field of data communications, they must also familiarise themselves with acronyms and jargon which may further confuse their understanding to the subject (Leung and Pilgrim, 1995).

Research into Computer Science Teaching and Learning

We are interested in uncovering the variation in the ways in which learners experience the learning of abstract concepts. By uncovering these variations, learners and teachers are able to gauge the effectiveness of and tailor the instructions used to teach abstract concepts. Current work done in this area stems from earlier work done by Booth (1989) in understanding how students learn to program. Like data networking concepts, programming concepts are equally difficult. Booth used the phenomenographic approach to uncover students' experiences in trying to grasp programming concepts. In her research, Booth classified the experiences of learning to programme into distinct yet somewhat related groups. These conceptions varied from seeing programming as a way of interacting with the computer, to seeing programming as a problem solving exercise. Learners who see programming in the former group would approach learning to programme using a superficial approach whilst learners who see programming as a problem solving activity approached programming using a deep learning approach. It is also possible to bring about a change in learner's conception from the former to the latter hence enhancing the experience of learning to program.

Berglund (2005) took this work one step further by investigating how students from final year computer science courses understand computer network protocols. In his research, groups of students from institutions in Sweden and the United States were required to collaborate in creating a network program to move a toy called the Brio Labyrinth over a computer network. Interviews were then conducted to uncover the variation in the students' experiences in completing the task and their understanding of computer network protocols. Emphasis was made on the variation in the understanding of the TCP/IP protocol suite. It is important to note that this study looked at the variation of understanding computer network protocols in groups of advanced computer science students; these students as a result of their advanced status have had a variety of experiences in learning networking units. There was again significant variation in ways in which learners experience the learning of computer network protocols. The variation of understanding ranged from describing, superficially, that computer network protocols as a way of communicating between two machines to a

deep understanding of the protocols described. However, students were able to contextually shift between the superficial understandings to the deep understandings of network protocols. It was discovered that contextual shift was possible if students were given a wide variety of experiences in their learning. The implications for teaching and learning are profound in that students need a variety of experiences in order to grasp difficult concepts. Instructions need to be designed to take into account these experiences.

Interestingly, recent QUT research into how introductory students learn to program, at both the undergraduate (Bruce et al., 2004a) and at the postgraduate level (Bruce et al., 2004b) revealed differences between students at the introductory level and Booths earlier work. This means we can't assume that advanced networking students have the same experiences in the subject as students at the introductory level.

Learning Networking at QUT

ITN 667 – Internet Protocols and Services is a unit taught at postgraduate level at the School of Software Engineering and Data Communications within the Faculty of Information Technology at QUT. The introductory unit gives students an in depth analysis to the TCP/IP protocol suite which is used on the Internet. Students are instructed in the traditional 2 hour lecture and laboratory work / tutorial format. The traditional OSI model is used to introduce students to the concept of layered communication. TCP/IP is then dissected and described in depth. Laboratory work and paper based tutorials are conducted to give students a variety of experiences in learning about the protocols.

In order to further allow students the ability to determine if they have grasped the concepts learnt, various self-paced non assessable web-based tutorials were written. Students are given immediate feedback to their answers. The tutorial incorporate context sensitive help screens to direct the student to hints and a variety of resources to enable them to discover the solutions to the tutorials. The help provided encourages students to seek the answers in the hope that this experience would enrich the students' understanding of the concepts presented.

A programming component is also built into the unit to give students a "physical" experience of the way communications protocols are built. The programming assignment requires the student to create an application which would enable network connections to occur between their computer and foreign computer via a middle machine called a proxy server. To experience the building of a network, students learn to create network connection end points called sockets. Once these sockets are created, data can then be moved between the end points. Students are then required to describe how TCP/IP performs these tasks.

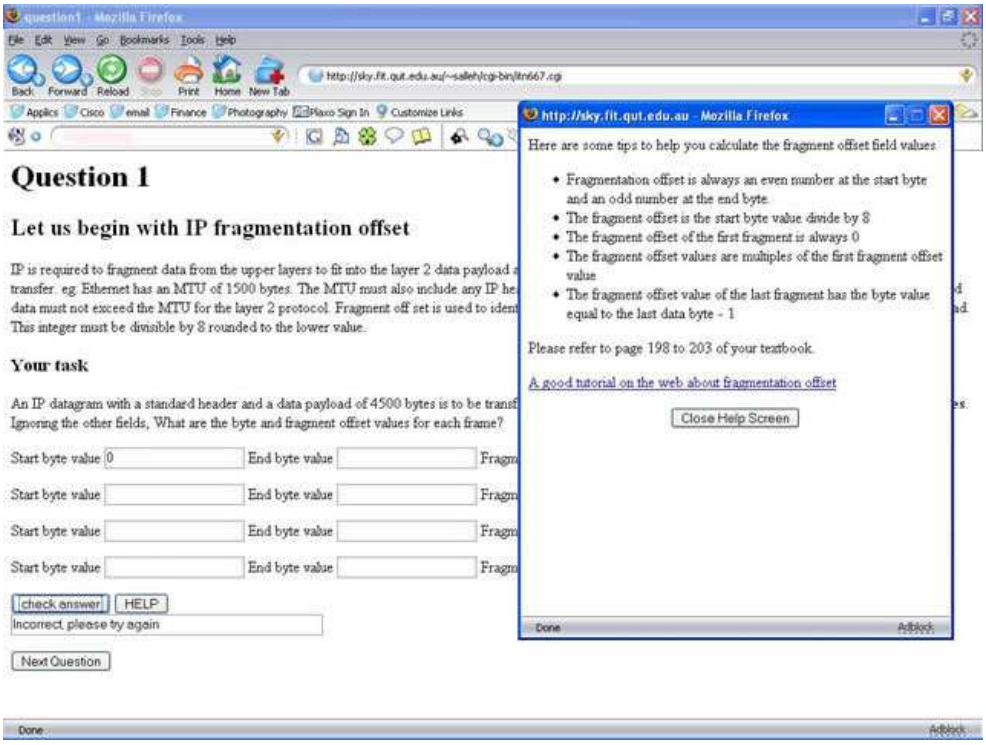

Figure 1 Example of the web-based tutorial

Research Questions Arising

We were interested in discovering the variation in learning experiences of students in this unit based on the multiple ways in which networking concepts were introduced and taught. In particular, we were interested in discovering the effectiveness of the context sensitive web-based tutorials in enhancing the students' experiences in learning networking.

Based on their learning experiences, we were also interested in discovering students' ways of seeing the network. In particular we were interested in learning if students could, from their perspective, explain "what" a network is and also "how" the network works.

Phenomenography – Research Approach

What is phenomenography?

> "Phenomenography is a research method adapted for mapping the qualitatively different ways in which people experience, conceptualise, perceive and understand various aspects of, and phenomena in, the world around them" (Marton, 1986)

The aim of phenomenography is to discover variation in ways of seeing or experiencing phenomena amongst groups of people. In order to do this, a variety of methods can be employed which can include semi-structured interviews or questionnaires. The aim is to allow the subject to freely describe their perceptions of the phenomena that is being investigated. From these interviews or questionnaires, categories of description are then extracted. These categories are the researcher's descriptions of the students' different ways of seeing the relevant phenomena. Variation between these categories are then

further examined and analysed. The aim is to provide the researcher with findings which could be used to improve teaching and learning. It is important that the outcomes from the research should be fed back into the teaching and learning process (Bowden, 2000)

The reason that the phenomenographic method approach was chosen is because we were interested in looking, qualitatively, at variations in the students' experiences and their conceptions of the network. We were interested in uncovering their perceptions of the "what" and "how" of the network phenomena. We were also interested in discovering whether the tutorials helped them in gaining understanding of the network and if so, how.

The Method

Participants for this research were randomly pooled from the ITN667 semester 1, 2005 cohort. An initial sample of 6 students volunteered. The students came from a variety of backgrounds, nationalities and genders.

Interviews were used as the primary data gathering technique for this study. Open questions were initially asked and students were allowed the time and liberty to answer the questions. Follow up clarifying questions were also asked to further probe into the students' perception of the phenomena investigated.

Questions asked

1. Explain to me your definition of a computer network?
2. What happens when a sender on your network sends a message over a computer network to a receiver on another network? Imagine that you are explaining this to someone who doesn't know much about networking, what would you say?
3. Can you tell me about what helped you come to this understanding?
4. Did you use the web-based self-help tutorials?
5. If not, can you explain why not? What might have encouraged you to use them
6. If yes, what parts of them did you use? How did you use them?
7. Did they help you and if so, how did they help you?
8. How did you come to know that the tutorials were available?
9. What do you think can be done to improve on the tutorials? How can they be made more intuitive for you?

The first two questions set the baseline from which their understanding of the computer network can be ascertained. The first question was used to probe the students' perception as to the "what" of the network. The second question refers to the "how the network works" part of the phenomena being studied. No factual corrections were made to their answers or comments. The reason for this was to compare the participants' use of the tutorials to their perceptions of the network, and to consider whether there may be any correlations between them. Question three sets the baseline for any past experiences they may have had on learning about the computer network. This question was then followed up by other questions to determine the parts of the course (i.e. the lecture, tutorials or programming components) that may have contributed to the student's understanding of the computer network. The other questions relate to the tutorials themselves.

The data acquired was transcribed verbatim and analysed to identify students' conceptions of a network as well as their conceptions of how a network works. A 'conception' or 'way of seeing' is a holistic expression of both the students view, together with the description of "what the network is", and "how it works", as they appear to the student. In a phenomenographic analysis descriptions of differences in conception are usually expressed in terms of both variation in meaning and variation in structure. These differences are captured in representative categories of description. In the pilot study conducted to date, it has been possible to identify different categories to the level of variation in meaning. Further development of the study will be conducted in order to capture variation in structure.

Results

We set out to discover the variation in students' understanding of the concept of a network, and how it works. From the transcript of the interviews, 2 major categories were uncovered for each of the "what" and the "how" of the phenomena being studied.

Variation in students' ways of seeing "what a network is"

Students saw the network either as a

a) A system of interconnected devices with associated protocols and structures to enable communication to occur.

Students in this category were able to describe in detail, the entire physical and operational structure of the network. They looked at the network as a system of interconnected devices and were able to include in their description the associated protocols and internal structure of the network along with how they relate to the operations of the network. They were able to describe in detail, and correctly, the entire operations of the network from when data leaves the sending entity to when it arrives at the receiving entity.

b) Two or more communicating entities.

Students in this category were only able to describe the surface description of the network. In general, they described the network in terms of the physical structure but did not take into consideration the internal structure of the network. Their definition of the network was not as verbose as those from the previous conception.

Variation in students' ways of seeing 'how' a network works

Students described how the network works in 2 distinct views. These are the

a) The holistic view of the network.

Students in this category were able to describe in detail the internal operations of the network. They were able to relate the operational parts of the network to the whole and were able to correctly identify the associated protocols to ensure that communication can occur within the network.

b) The atomistic view of the network.

Students in this category had some understanding of the internal operations of the network. They were able to describe parts of the internal network operations but did not quite know how to relate those parts of the network described to the whole operation of the network. There were also some confusion and misconception to some of the protocols that were described.

The separation between the two views is quite distinct. The more a student was able to describe the network operations holistically, the better the definition of the network given.

It appears that students who had an atomistic view of the network are surface learners and that students who saw the network holistically are deep learners, although this needs further investigation. On further questioning, it also appears that for those students who come from a culture where emphasis was placed on examination, focus tends to be placed on the parts of the problem and memorisation in order to help them pass the exams. This appears to emphasise the atomistic view of the network, and hence surface learning.

Variation in ways of using the tutorials

There were no significant variations in how students used the tutorials. However it may be that students who are atomistic learners used the tutorials to reinforce their atomistic view of the network. This was counter intuitive to the purpose of the tutorial in encouraging students to seek a holistic view of the network. This however, would need to be further investigated

Some questions that arose from this investigation are:

1. Are the frequent use of any forms of assessments, summative or formative, promoting atomistic rather than holistic learning?
2. Will the incorrect use of technology and certain learning design principles be counter-intuitive to deep learning?
3. If so, what can be done to improve learning design principles to encourage deep and critical learning?
4. Do we need to change our approach to assessment in order to foster deep and critical learning?
5. How do we foster a contextual shift from a superficial learner to a deep learner?

Discussion

One of our questions is about whether the forms of assessment used in this unit promote atomistic rather than holistic learning? This paper seeks to clarify linkages between formative assessments with student learning. It reflects Bloom's interest (1971) in Scriven's (1973) conceptions of 'formative evaluation' to teaching and learning practices. Bloom repositioned Scriven's notion of evaluation of curriculum whilst under development, to also describe the feedback opportunities provided to learners, that is, opportunities which are judged but not graded. Further investigations into these linkages, within discipline specific contexts, as informed by specific pedagogies, and placed within particular delivery modes and exchanges, are likely to be ongoing.

The value of formative assessment for student learning relies on a wide range of factors. The learner's orientation and motivation to pursuing studies in the discipline (Peat et al., 2004), the environment in which the formative assessment is delivered, the time and sequence of formative and summative assessment items, and perhaps most importantly, the type of feedback provided (Box, 2003). The areas of student orientation and feedback type are of particular interest to further work in this area – how can the technologies be designed to bring about deep learning?

A *transitional* effect has been detected in students' usage of formative assessment opportunities (Peat et al. 2004). Peat's findings indicate that learners are more likely to make usage of these opportunities the further they have progressed through a particular course of study. One proposed reason for this is that as students' levels of commitment and interest in a particular discipline increase, the more likely it is that a certain level of learner maturity and independence will inform their usage of such formative assessment resources. Other findings suggest that certain types formative assessment, particularly self-diagnostic quizzes may not do much in themselves to prepare for deep understanding of abstract concepts, but do play a role as a trigger for student motivation to develop problem solving skills (Swan, 2004).

Box (2003) suggests a number of feedback types and roles - which are of use here in considering the efficacy of the on-line tutorials. Her schemas involve four relationships: (i) Judicious teacher/responsive student, (ii) advisory teacher/judicious student, (iii) judicious peer/ responsive student and (iv) self-determining student.

> 'Judicious' indicates that the role of the person is to exercise good judgement about the quality of the artefacts, expressed as feedback that is wise, sensible, and assists learning. 'Responsive' indicates that the role of the person is to respond to feedback provided by improving the quality of the artefact. 'Advisory' indicates that the role of the person is to facilitate another's judicious role. 'Self-determining' indicates that the role of the person is to be judicious and responsive. (Box, 2003)

The on-line tutorials could therefore be considered as self-determining – a factor which may encounter tension when considering the *transitional* nature of formative assessment usage. Box has found that usage of self-determining feedback loops can be quite low – and can even inculcate hostility from some students.

Conclusion

We have sought to understand how students approach learning in one technical area. We have also begun to think about how learning design and the use of technologies can bring about the appropriate learning outcomes. The on-line tutorials are made available to an introductory networking unit for a cohort of 35 students. Considering the effects of transition and feedback type it is possible to suggest that these factors have contributed to the general finding that the self-help tutorials may have contributed to an 'atomistic' view of the unit material. Some of this may be accounted for via (i) student perceptions of the *position* of the feedback type in relation to the other learning opportunities that this subject has provided them, and also (ii) the *opportunism* or kinds of usage of the on-line tutorial tool.

Further investigation is required into resolving the tensions between providing formative assessment opportunities that help student build their understanding of abstract concepts, and a holistic view of data communications concepts.

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