Seeing is believing: using Data Visualisation for formative feedback in computer supported online learning collaboration

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Abstract: Professional Issues in Software Engineering (PISE) is a final year computer science module taught at the University of Limerick. PISE focuses on the ethical, legal and social consequences of the design, implementation and use of information systems. A central pedagogy to the module is the group-based approach to teaching and assessment. A Virtual Learning Environment (VLE), Moodle, has been used to facilitate this approach. However, the sheer volume of data created by student interaction with the VLE caused a problem of information overload for the lecturer. This paper describes the nature of the problem and the use of formative assessment to provide useful learner feedback. The paper finally discusses the use of Data Visualisation and a tool, DVReport, that was specifically developed for Moodle to enhance the learning.

Keywords: Moodle; DV; data visualisation; online learning; collaborative learning.

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Biographical notes: Joe Griffin has been investigating the use of internet-based tools for collaborative learning for many years. His focus has been in the domain of professional issues, specifically in computer ethics. The ongoing research aims to develop a multi-cultural and multi-institutional approach to teaching and learning in this domain. Future focus will be on collaboration with faculty and students in universities from non-western countries.

Julie Pichon is a Software Developer, with a keen interest in open-source software and education technology. She studied at the University of Limerick, Ireland for a BSc in Computer Systems and at Dublin City University, Ireland where she received a MSc in Software Engineering.

1 Assessing online discussions

Garrison et al (2001) have proposed a model, the Community of Inquiry as a 'framework for analysing critical thinking in computer conferences'. Using this model:

> deep and meaningful learning, ostensibly the central goal of higher education, takes place in a community of inquiry composed of instructors and learners as the key participants in the educational process.

It proposes that this interaction takes place through the interaction of three elements, Social presence, Teaching presence, and Cognitive presence.

Teaching presence, focuses on the design and management of learning sequences, provision of subject matter expertise, and facilitating active learning. *Social presence* is defined as the ability of learners to project themselves socially and emotionally in a community of inquiry. *Cognitive presence* (CP) is defined as

> "the extent to which the participants in any particular configuration of a community of inquiry are able to construct meaning through sustained communication."

Archer et al. (2001) argued that CP provides a framework that can be used to analyse the effectiveness of online discussion in 'supporting critical thinking in higher education'.

There are four categories in the CP element within the model of critical thinking:

- triggering
- exploration
- integration
- resolution.

Each category is defined using a set of descriptors (see Appendix 1 for these). The CP framework was the basis for assessing online communication and providing formative feedback to learners.

2 Moodle

Moodle is a VLE and is based on a series of learning activities. The social-constructionism philosophy that underpins its design has grown out of the constructivist paradigm (Dougiamous, 1998). It promotes the idea that learners will reach higher levels of critical thinking by not only constructing knowledge but by creating artefacts. These artefacts can be created collaboratively using many of the tools (called activities) in Moodle.

At the heart of Moodle is the activity known as the Forum. This is where online threaded discussions can take place.

Moodle also provided a facility to create scales and one was created based on the CP described above. This allowed each post to be graded according to these categories. Figure 1 shows the Rating option on a post.

This data was collected and stored by the Moodle system and could be accessed by different users depending on the system permissions.

Figure 1 Rating on a Moodle post

3 Formative feedback to enhance learning

Online courses are more effective when the students are committed to participating in the course and to learn. It is the responsibility of the teacher to develop an online environment that facilitates such a process, and the essential basis for this is to provide formative, individualised feedback (Nulden and Hardless, 1999). Formative assessment is about giving a student feedback on how he is doing in the course *during* the course rather than at the end. Its purpose is to enhance learning, as opposed to summative assessment, that is, an assessment 'of' the learning (Crook, 2001). It gives students a chance to see where they are wrong and adjust their behaviour; if they want to, to improve their grades as the course goes along. As for the teacher, it helps him to detect learning problems, although it can be difficult to manage, as providing regular feedback to many students can result in overload (Otsuka and Vieira da Rocha, 2002).

Externalising the student model, that is, offering students a view of their current knowledge, also makes them more aware of their own learning and how they can impact on it. Self-knowledge encourages reflection and gives the students more responsibility for their own learning, which can, in turn, make learning more effective (Kay, 1997). It helps them to understand their progress. Formative feedback enables such self-knowledge to be generated.

As a final point concerning the data to use in formative feedback, Bull and Nghiem (2002) recommend showing the student a model of other students: good ones, that could be used an objective; weaker ones, to comfort them on their own performance; and the class average. This is important because often, the level of knowledge a student have may make sense only in terms of what his fellow students know; therefore, providing them with a 'benchmark' on what their classmates know is necessary to make sense of their own model (Kay, 1997).

Using the CP framework enabled criterion-based feedback to be used for formative assessment. The number and size of posts, and the rate at which students posted to the discussion thread, had been established in earlier research (Griffin, 2004). This meant that, broadly, similar amounts of student work were available for the assessment of each learner. This, therefore, allowed use norm-referencing to determine how students were performing in relation to each other. Figure 2 shows a typical output.

Learners were also able to see how they were performing. Figure 3 shows the information available to each learner in Moodle.

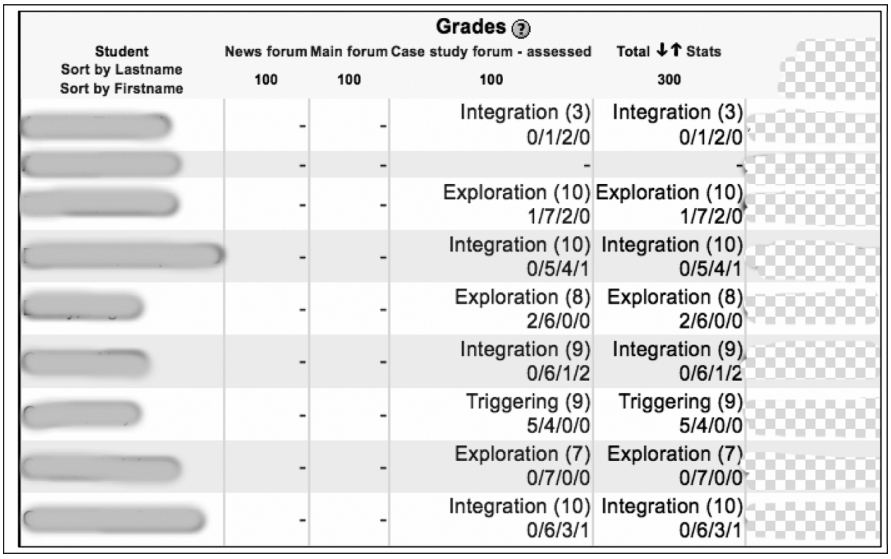
This view enabled the user to see in one view how many, and at what level, their posts had been graded. In the example above the learner has had 3 posts rated. (Because of the way the Gradebook is set up in Moodle an average grade is also shown, in this case

it is Integration.) The following line of data shows that there were no Triggering posts, one Exploration post, two Integration posts, and no Resolution posts.

One problem with this display was that it only showed criterion-based feedback. However, some students also indicated that reference-based would be helpful (those students who liked to compare their progress with others in their class).

It was, therefore, decided that it would be useful to make this additional data available. This was achieved by the development of a system whereby students could see their reference-based performance by displaying data showing the class average, the highest and the lowest class grade. These latter were displayed anonymously. This is now discussed.

Figure 2 Moodle standard output showing grades based on using CP framework to rate posts



Grades

Student Sort by Lastname Sort by Firstname	News forum 100	Main forum 100	Case study forum - assessed 100	Total ↓↑ Stats 300
[redacted]	-	-	Integration (3) 0/1/2/0	Integration (3) 0/1/2/0
[redacted]	-	-	-	-
[redacted]	-	-	Exploration (10) 1/7/2/0	Exploration (10) 1/7/2/0
[redacted]	-	-	Integration (10) 0/5/4/1	Integration (10) 0/5/4/1
[redacted]	-	-	Exploration (8) 2/6/0/0	Exploration (8) 2/6/0/0
[redacted]	-	-	Integration (9) 0/6/1/2	Integration (9) 0/6/1/2
[redacted]	-	-	Triggering (9) 5/4/0/0	Triggering (9) 5/4/0/0
[redacted]	-	-	Exploration (7) 0/7/0/0	Exploration (7) 0/7/0/0
[redacted]	-	-	Integration (10) 0/6/3/1	Integration (10) 0/6/3/1

Figure 3 Student view of assessment feedback

[redacted]	-	-	Integration (3) 0/1/2/0

4 Using Data Visualisation for formative feedback

Moodle provided a number of different methods to extract data using the Moodle report functions. However, the sheer volume of data that a large cohort creates made it difficult to spot trends or learners who may require assistance.

Data Visualisation (DV) is a technique that uses graphical representation to display complex data sets and abstract important information (Tufte, 2001). DV is important because graphical representations of data are easier to understand than text or tables of raw data, since they enable the user to take in the data all at once rather than by chunks. This is because image processing and pattern recognition are two strengths of the human mind, whereas processing large tables of data takes more time and increases

the likelihood of misinterpretation or missed information (Wright, 1999). Graphics should show facts about data, so as to reveal their meaning and offer new insights; their goal is to help reasoning about the data, by freeing mental resources (such as memory) and bringing out patterns (Mazza, 2004).

To do so while remaining true to the data, Tufte (2001) advises to keep in mind "the question at the heart of quantitative thinking: 'compared to what?'" We should always keep in mind what we are using the data for, what information we want to get out of it. In this study it was to give formative feedback to students and to let lecturers know how students performed as the course continued. Well designed visualisation also enables the reader to get the big picture at one glance, and also see the details while taking the time to look at its different parts, as expressed by Tufte's (1990) idea of micro- and macro-reading.

Data Visualisation is used in a wide range of domains, to represent very different types of data: from organisation charts (Lamping et al., 1995) to the human genome (Card et al., 1999) to the visibility and size of websites (Bentford et al., 1999).

A tool, DVReport, that used DV to display norm- and criterion-based data was developed and incorporated in the Moodle VLE.

Students used DVReport for formative feedback. Lecturers used the tool to view up-to-date qualitative and quantitative data on student online behaviour in Moodle.

The requirements specification for DVReport had two foci, one for lecturers and one for students.

For the lecturers the focus was to evaluate students' progress by providing easy access to data on student interaction with Moodle. This was to be achieved by providing visualisation to:

- display all students interactions with the forums on Moodle showing the number of posts, views and discussions started, the quantitative data
- display the formative assessment for each student gathered from the CP categorisation of posts, the qualitative data
- show the lecturer how the progress of a student compared with that of other average, worst and best students in the class, both quantitative and qualitative data.

The focus for the student was to improve achievement by providing formative feedback as a means to evaluate their progress. There were two specific aims in achieving this:

- provide students with a visualisation enabling them to compare their own progress with that of other students in the class (average, worst, best) on the number of posts, views and discussions started, the quantitative data
- provide qualitative feedback by displaying for students their progress compared with that of other students in the class (average, worst, best) gathered from the CP categorisation of posts, the qualitative data
- offer different types of visualisations so that the student can choose the one that helps them most because people understand graphical data differently.

In the early stages of the module students used Moodle for a number of reasons.

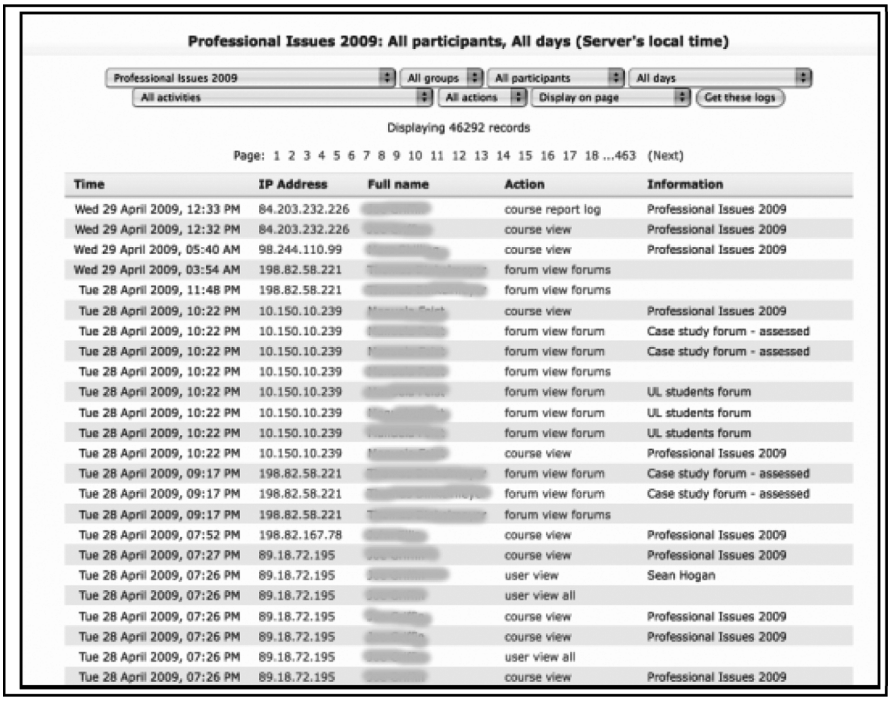
Social stage: where students familiarise themselves with the system and participate in discussions that were not assessed.

Group formation stage: where students formed groups and managed different organisational issues such as selecting a case study for the assessment.

Neither of these were assessable activities but lecturers needed to know that all students were contributing.

As was discussed above, Moodle records a large amount of data on user interactions with the system including how often resources are accessed, whether the user views the resource or adds material. The system also records the time and date of each interaction. All of this is displayed in table form such as in Figure 4.

Figure 4 Usage logs on Moodle



Professional Issues 2009: All participants, All days (Server's local time)

Professional Issues 2009 | All groups | All participants | All days | All activities | All actions | Display on page | Get these logs

Displaying 46292 records

Page: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...463 (Next)

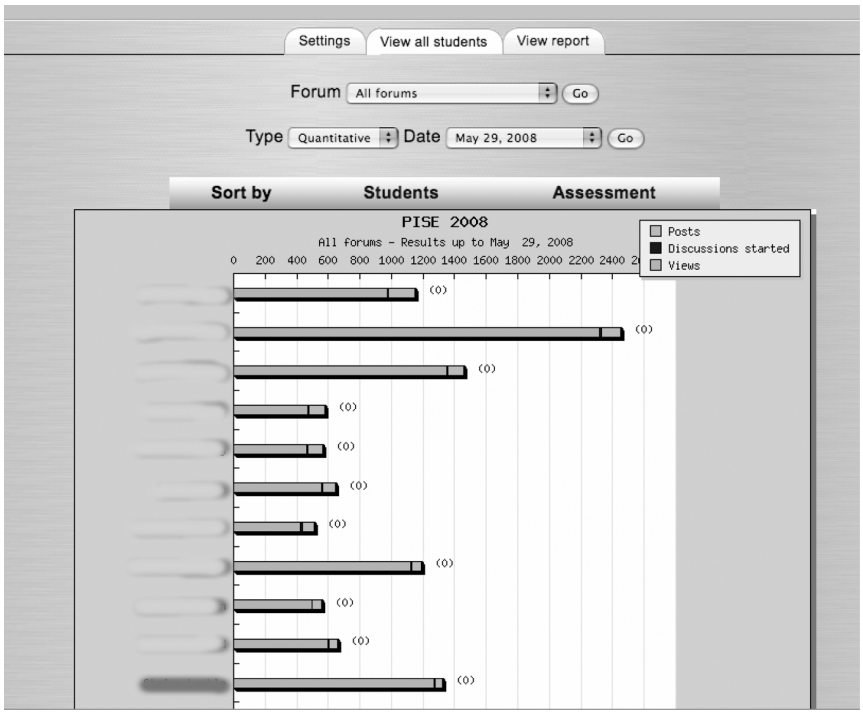
Time	IP Address	Full name	Action	Information
Wed 29 April 2009, 12:33 PM	84.203.232.226		course report log	Professional Issues 2009
Wed 29 April 2009, 12:32 PM	84.203.232.226		course view	Professional Issues 2009
Wed 29 April 2009, 05:40 AM	98.244.110.99		course view	Professional Issues 2009
Wed 29 April 2009, 03:54 AM	198.82.58.221		forum view forums	
Tue 28 April 2009, 11:48 PM	198.82.58.221		forum view forums	
Tue 28 April 2009, 10:22 PM	10.150.10.239		course view	Professional Issues 2009
Tue 28 April 2009, 10:22 PM	10.150.10.239		forum view forum	Case study forum - assessed
Tue 28 April 2009, 10:22 PM	10.150.10.239		forum view forum	Case study forum - assessed
Tue 28 April 2009, 10:22 PM	10.150.10.239		forum view forums	
Tue 28 April 2009, 10:22 PM	10.150.10.239		forum view forum	UL students forum
Tue 28 April 2009, 10:22 PM	10.150.10.239		forum view forum	UL students forum
Tue 28 April 2009, 10:22 PM	10.150.10.239		forum view forum	UL students forum
Tue 28 April 2009, 10:22 PM	10.150.10.239		course view	Professional Issues 2009
Tue 28 April 2009, 09:17 PM	198.82.58.221		forum view forum	Case study forum - assessed
Tue 28 April 2009, 09:17 PM	198.82.58.221		forum view forum	Case study forum - assessed
Tue 28 April 2009, 09:17 PM	198.82.58.221		forum view forums	
Tue 28 April 2009, 07:52 PM	198.82.167.78		course view	Professional Issues 2009
Tue 28 April 2009, 07:27 PM	89.18.72.195		course view	Professional Issues 2009
Tue 28 April 2009, 07:26 PM	89.18.72.195		user view	Sean Hogan
Tue 28 April 2009, 07:26 PM	89.18.72.195		user view all	
Tue 28 April 2009, 07:26 PM	89.18.72.195		course view	Professional Issues 2009
Tue 28 April 2009, 07:26 PM	89.18.72.195		course view	Professional Issues 2009
Tue 28 April 2009, 07:26 PM	89.18.72.195		user view all	
Tue 28 April 2009, 07:26 PM	89.18.72.195		course view	Professional Issues 2009

As can be seen the data is displayed as a table and the different types of information can be difficult to extract especially when there is a large amount of interactions. The screenshot above is of the first of 463 pages of data to be shown! (Individual students, specific activities or certain days could also be selected but each of these produced separate sets of data that were not easy to compare.)

DVReport produced the following output of quantitative data for the lecturer view.

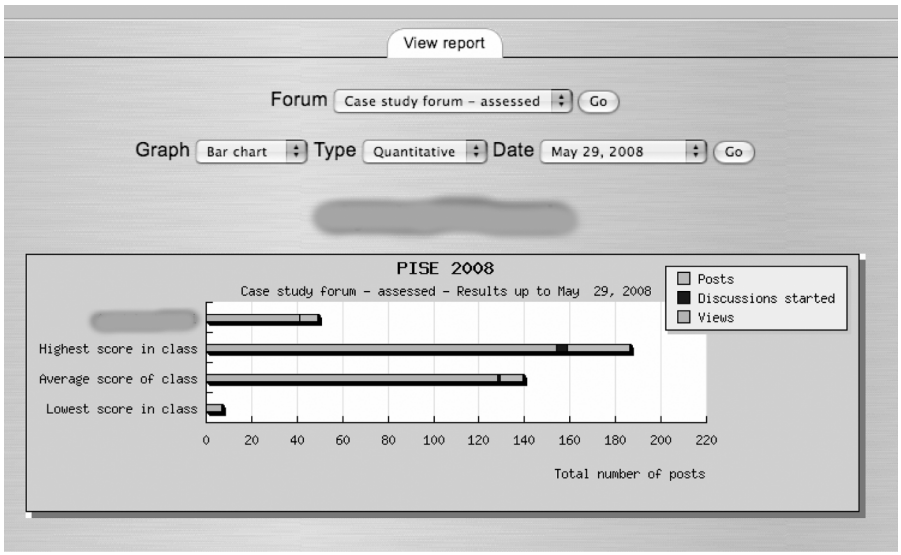
As can be seen, it is easy to identify individual student interaction with Moodle. Comparison of the interactions (viewing posts, starting new discussions or adding to existing threads) for each student could easily be seen with a single view. In Figure 5 the second student's data would alone have taken many pages of the Moodle log to display, as at this stage there were over 2400 interactions.

Figure 5 Lecturer view of graphical output from DVReport



The same data from the student's point of view can be seen in Figure 6. The first line in the output showed the student's own behaviour. The following lines showed the highest, lowest and average in the class levels of online activity, without the identities of those students being revealed.

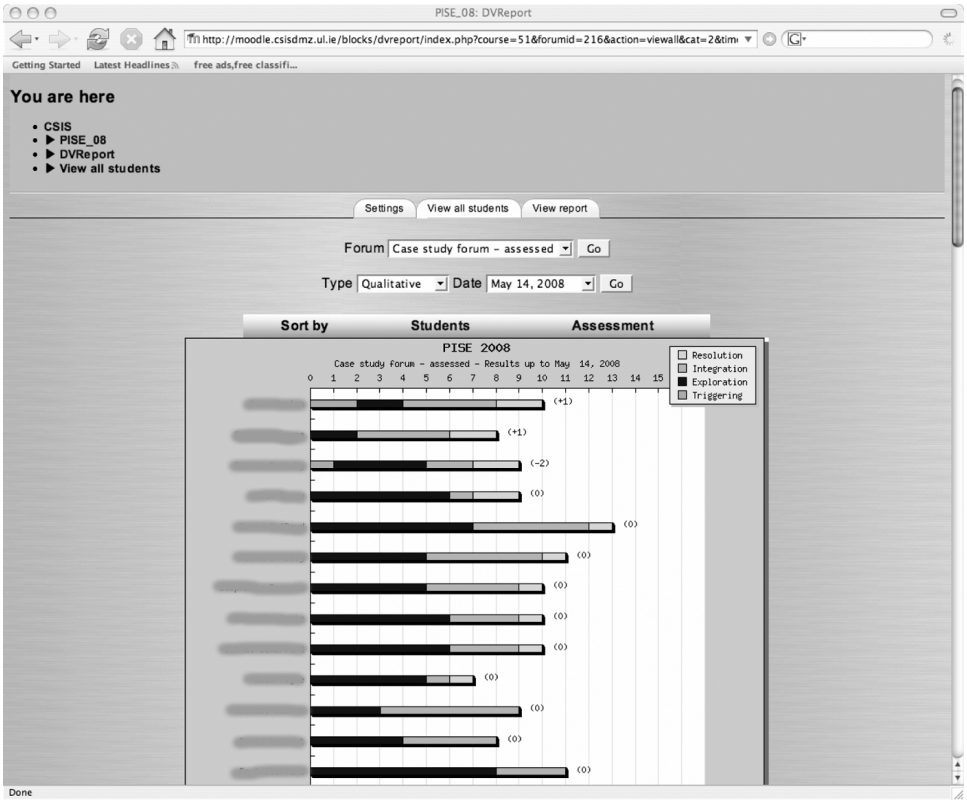
Figure 6 Student view of quantitative data



The second kind of feedback to display was qualitative. This was the aggregation of ratings following the CP categorisation process as described above. As each post was individually rated on a weekly basis, this enabled production of formative feedback data.

Moodle showed this data in a spreadsheet format and as it was difficult to decipher with large data sets. With DVReport this data were displayed graphically and it was easier to abstract their meaning. Figure 7 shows the lecturer's view.

Figure 7 Lecturer's view of qualitative data output using DVReport

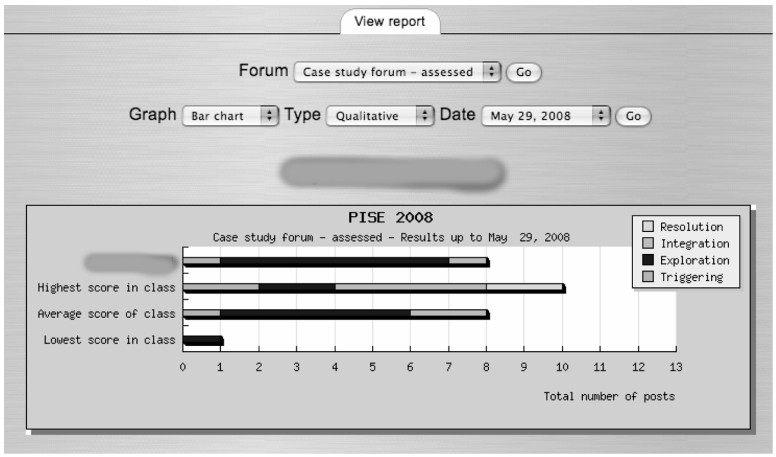


The graphs are easily digested and the relative position of each student can also be seen at a glance. With these different outputs it was possible for the lecturer to be fully aware, easily and efficiently, of student interaction with Moodle and their progress at each stage in the ethical dilemma assignment. Intervention could take place if a student was not achieving as much as was expected.

Students had a different view, from the lecturer, of the qualitative data. As with the quantitative data, the students cannot only identify their own details by name but are also shown the highest, average and lowest score for the entire class. This enabled anonymity to be maintained while, at the same time, providing students with reference points to compare their own performance with the others in the class. This is shown in Figure 8.

From the students' perspective, with DVReport the learners are able to judge their own performance using both norm- or criterion-referencing.

Figure 8 Student view of qualitative output from DVReport for assessed posts



5 Conclusion

Using ICT to support group-based learning and assessment has provided many tools for lecturers and students. However there are still potential problems for lecturers in dealing with large cohorts and for students in determining their formative feedback. One method that can provide for a meaningful learning environment is the use of online discussions but these carry their own potential problems. Individual contributions often need to be determined and this can be achieved by using a formal method for assessing individual posts.

The application of an assessment classification based on the categorisation framework was developed to measure critical thinking in computer conferences. However, the volume of data produced made abstraction of meaning difficult. A tool was developed to enable DV to be applied to facilitate this. Student feedback strongly indicated that DVReport was a useful tool and that it contributed to their ability to determine how they were achieving in PISE. It enabled easy abstraction of important data for both norm- and criterion-referenced feedback. DVReport also enable the lecturer to see more easily how each student was performing and to undertake educational intervention at an early stage.

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Appendix 1

Table 1 Categories for analysis of cognitive presence in community of inquiry

Type	*Descriptor*	*Indicator*	*Process*
Triggering	Evocative	Recognising the problem	Presenting background information that culminates in a question
		Sense of puzzlement	Asking questions Message that take discussion in a new direction
Exploration	Inquisitive	Divergence within the online community	Unsubstantiated contradictions
		Divergence within a message	Many different ideas/themes in one message
		Information exchange	Personal narratives/descriptions/facts (not used as evidence to support a conclusion)
		Suggestions for consideration	E.g., 'Does that seem about right?', 'Am I way off the mark?'
		Brainstorming	Adds to established points but does not systematically defend/justify/develop addition
		Leaps to conclusions	Offers unsupported opinions
Integration	Tentative	Convergence -among group members	Reference to previous message followed by substantiated agreement, e.g., 'I agree because'
		Convergence – within a single message	Justified, developed, defensible, yet tentative hypotheses
		Connecting ideas, synthesis	Integrating information from various sources – textbooks, articles, personal experience
		Creating solutions	Explicit characterisation of a message as a solution by participant
Resolution	Committed	Vicarious application to real world	
		Testing solutions	Coded
		Defending solutions	

Source: Archer et al. (2001) and Garrison et al. (2001)