# Connecting Learning Environments Using Electronic Voting Systems


**Quintin I. Cutts**

Department of Computing Science
University of Glasgow
Glasgow, Scotland

quintin@dcs.gla.ac.uk

**Gregor E. Kennedy**

Biomedical Multimedia Unit
Faculty of Medicine, Dentistry and Health Sciences
University of Melbourne
Melbourne, Australia

gek@unimelb.edu.au



## Abstract

Many educational theories depend on learning as a process of dialogue between teacher and learner. Traditional university methods such as lectures and tutorials do not facilitate dialogue since students are unable or unwilling to speak out. The use of an electronic voting system in lectures, where all students can respond to questions set by the lecturer with the aggregated results displayed to the class, aims to alleviate barriers to dialogue in lectures and so improve learning. A recent study, by the authors, of a three-year use of a voting system in introductory programming lectures has shown that response rates by students are lower than expected. This paper outlines the educational purpose of using the system in this lecture course and postulates reasons for the low response rates. Based on these reasons, the paper presents an educational framework whereby students' votes not only enrich the lecture environment but are also used to facilitate learning in small group teaching sessions and the students' self-study environments.



*Keywords:* dialogue, feedback, cognitive processing, introductory programming, learning environments


## 1 Dialogue in Learning

Amongst the numerous processes involved in learning, many learning theories and models depend on cognitive processing and feedback (e.g. Kolb 1984, Laurillard 2002). This paper is written from the perspective of one such model, that of Laurillard, in which learning is a process of dialogue between teacher and learner. Each receives feedback on the learning process when they receive a communication from the other, and they process this feedback against their current understanding of the particular learning activity, making adjustments as necessary, before responding. The dialogue continues until there is a mutually agreeable understanding between both sides.

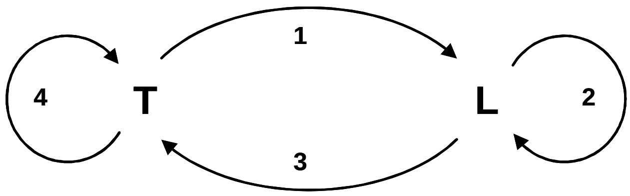


Figure 1: A simplified version of Laurillard's dialogue model

This is most easily seen in a one-to-one learning situation, as depicted in Figure 1, a simplified version of Laurillard's model. Here, the teacher, T, explains a topic or asks a question (1). The learner, L, processes the topic or question against their current understanding, (2), and then responds accordingly (3). The teacher compares this response with their own viewpoint (4) and if there is a discrepancy, continues the dialogue with appropriate feedback, remediation or review material (1). There may be many cycles of communication and processing before the learning is complete.

Whilst learning research suggests the necessity for dialogue of the kind described above, typical university learning environments tend to minimise these activities. It is hard for students to actively process the material delivered in lectures, and there is even less opportunity for dialogue to assess and hone understanding. Self-directed study after lectures aims to initiate cognitive processing of the material, but there is often little opportunity for any kind of dialogue unless the student has formed a study group. Typical 'small group' tutorials of around 10-20 students foster only limited dialogue as students may not have prepared for the session, or be at different levels to other group members, or be nervous of speaking out in front of them. Tutors have little information about a student's current progress, gleaning what information they can from submitted work. On this basis, written or verbal feedback can only be provided some significant time after the original learning attempt took place, by which time students appear often to be only interested in the marks anyway. In a subject such as programming, under discussion in this paper, the one exception to this depressing view of university learning is in staffed laboratory sessions, where one-to-one Laurillardian dialogue does take place, particularly in the presence of a skilled tutor who can encourage the student to think deeply about their problems. It is our viewpoint however that over-emphasis on working in front of a machine can hinder students' development of problem analysis and algorithm development skills, and students should be encouraged to develop and discuss solutions away from the machine. For this reason it is important to maintain both tutorials and laboratories.

## 2 Using an Electronic Voting System in Programming Lectures

An electronic voting system (EVS) enables students to answer multiple choice questions set by the lecturer. The student delivers their answer using a handheld transmitter, and the answers are collected by a receiver attached to a computer which displays the aggregated responses as a graph for the lecturer and students to see. An EVS can support dialogue as presented in the learning model of Figure 1. An EVS question is presented by the lecturer, step (1), to be processed by the students, (2). They can all respond (3), and this response is processed by the lecturer, (4), before feedback is provided on the various responses received and maybe another question asked to reinforce learning, (1) again.

This simple mechanism has been used in a number of ways to support learning. Because the responses are anonymous, a majority of students typically respond, and the graph can be used as a starting point for discussion about the concepts underlying a question (Mazur 1997, Dufresne et al, 1996). It appears that once students have committed to an answer, they are more willing to discuss it. In a more traditionally-structured lecture, an EVS can be used periodically throughout the lecture to assess understanding of the material being presented and take corrective action when necessary, e.g. (Stuart et al, 2004). Other uses of an EVS include large group tutorials to identify problem areas quickly (Wit 2003), exam preparation sessions to familiarise students with the kinds of questions they will face (Eliott 2003), and large group discussion sessions designed to engage students with problems highlighted in earlier assessed work (Cutts et al 2004b).

This paper focuses on the use of an EVS in a large introductory programming class, from 250-450 students, for three years in yet another mode. The primary purpose of asking questions in these lectures is to get students working with the practical stuff of the subject as soon as possible. In such a practical discipline as programming, there is only so much that can be lectured or demonstrated, and the sooner the student can actually be working with language constructs and attempting to solve problems, the better. This is a precept of the active learning community. In addition, such periods of activity break up the lecture, improving concentration (Bligh 1998). Referring back to the learning model of Figure 1, the aim is to get the students actively processing the material in step (2) as early as possible in the learning cycle. Before an EVS was used in the programming lectures, short exercises were set periodically during each lecture and students given time to work on them. This development is reported in detail in (Cutts 2001). Many students did not attempt the questions, however, preferring to wait to discover the answer from another student or the lecturer. For the lecturer, it was frustrating both to see these non-attempts and also not to be able to discover how those students who attempted the questions were progressing. The use of an EVS aims to alleviate these frustrations. The secondary purpose of the EVS-use in these lectures is the opportunity to correct any misunderstandings at an early stage, steps (3), (4), and then (1) again from Figure 1.

One of the valuable practical aspects of this style of use is that it does not require a complete re-working of the lecture material or format to introduce the technology, unlike Mazur's Peer Instruction format, which tends to convert the lecture into a large scale tutorial or discussion session (Mazur 1997). The lectures essentially follow the same format, although the introduction of material and the length of worked examples can be reduced in favour of asking, working on and responding to questions.

## 3 Examining EVS Use in Programming Lectures

The use of an EVS in programming lectures introduced here has been thoroughly evaluated. The evaluation is based on end-of-course student questionnaires and short interviews with individual students, and on qualitative and quantitative analysis of the response data that is automatically collected by the EVS. The quantitative analysis is reported in more detail in (Kennedy and Cutts, forthcoming), where the principal aim was to see whether EVS-use related to improved performance.

Students report that they strongly approve of the use of an EVS in lectures. They enjoy being able to contribute to lectures and can see that they can have an effect on the course of the lecture by being able to provide feedback to the lecturer. They like the anonymous nature of the responses, in that their peers cannot see their individual responses. They are aware that the lecturer can access individual responses and over 80% are not troubled by this. They report that they are twice as likely to construct an answer to a question when the response is via the EVS, as opposed to when it is with a show of hands.

Despite the students' apparent enthusiasm, many students do not make use of the system. Each student is given a transmitter for the duration of the course, and there is no assessment requirement attached to using it. In any given lecture, around 15% of students are absent and a further 15% of students forget their transmitter, as measured using a periodic show of hands. An analysis of some response sets for the questions in a lecture showed additionally that many students who do have their transmitter at the lecture do not answer all questions. For some questions, only about half of the available transmitters were used, although the typical level of non-response is around 20%.

The quantitative analysis of the student response data in conjunction with students' mid-course and final assessments showed that students who used the EVS more often did perform better in assessments, although the level of correctness of their responses did not correlate. In other words, a greater number of responses from a student matches with a higher outcome, but the correctness of those responses is not important. Despite this, when looking at only those students who responded frequently (to more than two thirds of questions), a significant proportion who responded with the incorrect answer also performed poorly in the assessments. Additionally, it was also noted that the number of responses per question dropped on average over the duration of the course.

After examining the response data more closely, the lecturer became aware that, at times, serious misinterpretations of the response graph were made during the lecture. Once the responses are displayed, the lecturer has only a few moments to decide on the appropriate course of action, and the general shape of the bar chart may prove more powerful than the actual numbers. The misinterpretation tended to favour a view that most of the class understood a point, when in fact sometimes over half the class had either answered incorrectly or else not answered at all. This occurred because (a) the chart appeared to only have one or two large bars, whereas in fact the number of student votes contributing to those options with lower votes was significant, and (b) as mentioned above, the number of students not voting was large. Such a misinterpretation would cause the lecturer to continue on the assumption that the class understood the material when in fact many did not.

The education model of Figure 1 was developed towards the end of the three-year use of the EVS, in order to better understand the processes going on in EVS-enabled lectures. On reflection, it is clear to the lecturer that typically only a single cycle of the dialogue model was completed on most topics. The students answered a question and the lecturer commented on their responses, taking more care over those questions where many students had answered incorrectly. So, the dialogue cycle went from step (1) right round and back to (1) again. However, it rarely continued beyond this point. The students were not routinely given the opportunity to re-check their understanding, step (2), or present it back to the lecturer, step (3), via a second question on the same topic, a crucial aspect of the dialogue model of learning.

In summary:

- Students were enthusiastic about the system.
- Significant numbers of students responded to EVS questions only intermittently.
- In general, students who responded to questions fared better in assessments. However, over a third of students who responded to more than two thirds of the questions did not respond correctly and also did not perform well in assessments.
- The lecturer misinterpreted the response graph on occasion, believing that more students were answering correctly than really were.
- Only rarely did the lecturer continue the Laurillardian dialogue cycle of Figure 1 beyond the first cycle.

## 4 Explaining Low Numbers and Poor Correctness of EVS Responses

A number of reasons will now be postulated to explain the findings given in the previous section. None of these can be proven without further work. Instead, the final contribution of the paper is an extension of EVS-use that extends the conversational framework of learning outlined in Figure 1 beyond the lecture theatre in a way that addresses the postulates while at the same time enables each of them to be verified. Each postulate is described and then lettered and summarised.

Although students indicated through questionnaires that they were aware of the general benefits of the voting system and how they made lectures more enjoyable, they may not have personally seen the benefit in working hard themselves on each problem. They may not understand the crucial part they must play in the learning cycle of Figure 1, thereby breaking the cycle at steps (2) and (3). This leads to postulate (A).

*A: Students are unaware of the educational rationale demonstrating the value to their own learning of both working out an answer to a question and submitting it with the EVS*

Students may have initially been working and responding to questions, but because of the lecturer's misinterpretations of the response graphs or lack of time to address all misunderstandings, failures at steps (4) and then (1) in Figure 1, many students would not be getting any remedial assistance from the lecturer even though they got the question wrong. With little reward for the work such students were investing in answering questions, enthusiasm to undertake this work would wane, in line with long-established research on the effects of positive feedback on human behaviour (Annett 1969). Again the learning cycle of Figure 1 is broken at steps (2) and (3).

*B: Lack of effective remediation limits learning and reduces over time the enthusiasm to work out an answer or respond to a question*

As the lecturer continues to misinterpret the response graph or is unable to spend the necessary time to address all student misunderstandings, the gap between the lecturer's expectation of the questions that students should be able to tackle and the reality of the students' level of understanding widens. This is especially true of a subject like programming where the concepts develop one upon another in a highly stepwise fashion. Eventually students are unable to make any successful attempt at answering the question, step (2) in Figure 1, and so cannot respond. Although most questions include an "I don't know" category, students rarely make use of this response option.

*C: Some students, still possibly enthusiastic to answer, are unable to do so because their level of understanding has fallen too far behind*

Some students may not be able to get their response submitted due to technical issues. In large classes of up to 300 students, the infra-red receiver technology used can occasionally become jammed due to large numbers of responses and there have been reports of students believing their response had been accepted when in fact it had not. This is a failure at step (3) in Figure 1.

*D: There may be technical reasons for reduced response rates*

Students may not be in a position to construct a sensible answer, as above, but because the technology is something of a novelty, they still choose to respond with a meaningless answer. Whilst still taking part in step (3) of the learning cycle of Figure 1, this response is not based on any sensible mental processing at stage (2).

*E: Some student responses are not based on any serious processing of the question, resulting in no learning benefit to responding*

The questions themselves may be defective for a number of reasons. Students may not be able to understand what is being asked through poor or confusing wording, a failure at step (2). Remediating on the basis of the question responses alone requires that each response identifies a particular misunderstanding: when many students choose a particular incorrect answer option, the aim is that the lecturer explains this misunderstanding such that the student is able to correct themselves. This is a failure at steps (4) and (1). It is challenging to write questions that accurately categorise students' misunderstandings.

*F: Questions may be unfit for the purpose, both through their phrasing and through their effectiveness in categorising misunderstandings*

Lack of further questioning after feedback has been provided on incorrect answers prevents students from deepening and checking their new understanding. Further cycles around the loop of Figure 1 are missing. The principal purpose of answering questions in these lectures is for students to work actively on the material. If they do this incorrectly the first time, they need an opportunity to work with a new and hopefully corrected understanding as soon as possible afterwards.

*G: Students rarely have an opportunity to reinforce the beneficial effects of any remediation directly afterwards*

Whilst the response graphs are sometimes misinterpreted by the lecturer, there are times when he/she is fully aware of the range of misunderstandings, but cannot address them all due to time pressure. There is an inevitable trade-off here, recognisable to any lecturer, between ensuring that every student understands a point and keeping the understanding of the majority of the class moving forward. This issue is explored in more detail in (Cutts et al 2004a).

*H: For the benefit of the class as a whole, there is sometimes not time to address all misunderstandings during the lecture*

## 5 Integrating Learning Environments

As described in Section 1, dialogue is not well-supported in typical university learning environments. Sections 2 to 4 described how the use of an EVS is intended to aid learning in lectures by increasing the potential for dialogue, but also how evaluation and analysis has shown that the improvement is not as great as would be hoped. A consideration of the use of voting systems in lectures alone appears to be insufficient to improve learning, and so this section proposes an integrated learning environment that makes use of EVS response data to bind lectures, student self-study time and tutor-led sessions. The principle aim is to facilitate and increase the opportunity for dialogue between students and staff across all these learning environments. A representation of the proposed integrated environment is given in Figure 2, and the various components will now be described.

The lecture is the starting point for learning, with EVS-enabled discussion promoting active learning in the lecture theatre, as before. However, the experience of the programming class shows that improved remediation will improve the chances of all students keeping up with the class. Improving the quality of the questions and spending more time on remediation will help here, addressing postulates B, F, and G, but postulate H shows that there is a limit to the improvements expected down this path. Instead, it is acknowledged that students will leave the lecture theatre not understanding all the material covered. However, the questions answered during the lecture provide an indication to both lecturer and student of the material of the lecture that must be reviewed.

The first step is to make the data collected during the lecture available to staff and students. This is achieved by putting the questions and responses onto the web. Immediately after a lecture, the lecturer will review the class responses, annotating the web record with further comments about the various answer options that the students chose, depicted in the Review box in Figure 2. This acknowledges the fact that the lecturer has very little time in the lecture to evaluate the responses from the students, and the additional time for reflection gives the lecturer an opportunity for further analysis. Additionally, further questions can be set, honing in particularly on those areas shown to be most challenging to this cohort of students. Furthermore, the lecturer allocates up to a quarter of the next lecture to a review of the issues that came up in the previous lecture. This may consist of clarifying material or of further questions aimed at checking whether students have caught up on the necessary material. The lecturer annotations and lecture review component address postulates B, G and H.

After a lecture, students can access the web record of the EVS questions, responses and lecture annotations during their own personal study time. Note that students can access the aggregated class responses and their own individual response, but not the individual responses of

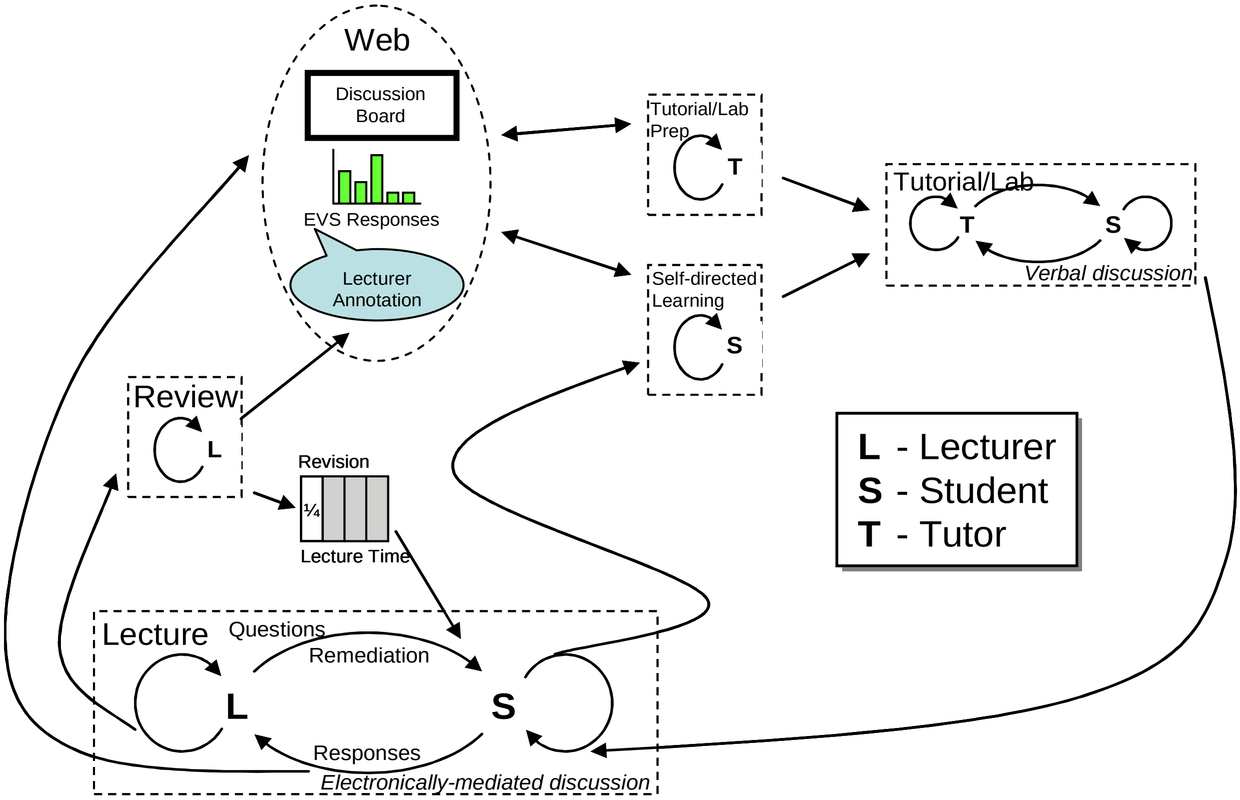


Figure 2: Integrated Learning Environment

other students. In addition, where a student has missed a lecture (recorded as not having answered this question), they are required to answer the question before they can see the correct response, or the aggregated class response. This information resource should assist students in determining to which areas of the material they should pay most attention. Where a student is unable to make progress on their own, a discussion board is available alongside each question and any student may place a request for clarification, to be answered by other students, tutors or the lecturer. This addresses postulates B, C, G, and H, but does depend on A being successfully addressed.

Tutorial and laboratory sessions are held in groups of around 15 students. The course tutors have access to the EVS response records for the students in their group, both aggregated and individually. The advantage here is that a tutor can go into a session with an up-to-date view of their students' understanding based on responses given in the most recent lecture, at most only a few days ago. Either the whole group can be addressed when most or all students have demonstrated a similar lack of understanding, or else individual students can be approached on particular topics. This is recognised to be of most benefit for those quiet students who are rarely willing to come forward with their own misunderstandings. Use of the response data in this way may seem intrusive to some. However, in end-of-course evaluations, over 80% of students said they were happy for staff to use the data in this way. Additionally, in the lecturer's opinion, it is only an extension of any attendance- or submission-checking mechanism which might result in a pastoral advice or warning letter from the tutor or course leader. Indeed it is a significant improvement on these mechanisms, because the information on the student's progress is far more specific. Tutor preparation addresses postulates B, C, G, and H.

The expectation is that the preparation by both students and tutors will lead to lively discussion in these sessions, something that is often absent from 'small' group sessions as students struggle to overcome the barriers to speaking out in front of their peers. In addition, the increased information available about student progress in general may help students to appreciate that they are rarely alone in not understanding elements of the course, and so reduce barriers to communication throughout the course structure, even to the point where students are more willing to raise issues independently during both lecturers and tutors.

To address postulates A and E, the educational framework will be fully explained to the students in order to encourage them to make full use of the environment. It is essential that the tutors use the information available to them in a supportive manner rather than be overbearing with it. The key is to repeatedly encourage students to focus on what they need to do to succeed in the course, while creating an environment in which it is accepted that mistakes will be made, with no embarrassment in discussing them with staff and other students.

Finally, postulate D has been addressed by adjusting the reponse gathering mechanism, thereby reducing the possibility of a student incorrectly believing that their response had been collected. Also, the graphs have been improved to reduce the likelihood of the lecturer's misinterpreting them.

It was pointed out in Section 4 that none of the postulates for poor response rates or low levels of correct answers could be proven without further expensive measurement. With this integrated system, tutors will be encouraged to keep a record of their interactions with students, noting the reasons for student not answering or answering incorrectly. This will be valuable feedback for verifying the postulates or improving the overall framework.

## 6 Conclusions

EVS use has been widely reported as a successful innovation in large group teaching. The recent quantitative analysis by the authors of three years of use in programming lectures, one of the first of its kind, showed a favourable correlation between a student's use of the EVS and their final outcomes. However, it also highlighted a number of anomalies. This paper has picked up on the anomalies and identified a series of possible reasons for them. The integration of learning environments presented in the final section addresses all the proposed reasons. At a reasonable cost, it has the potential to significantly increase the number of cycles around the learning loop by both lecturer and students, and thereby enhance learning. The next step is an evaluation of the integrated environment in action.

## 7 References

Annett, D. (1969): *Feedback and Human Behaviour.* New York, Penguin.

Bligh, D. (1998): *What's the Use of Lectures?*. Exeter, Intellect.

Cutts, Q., (2001): Engaging a large first-year class. In *Reconstructing Professionalism in University Teaching.* 105-128. WALKER, M. (ed), Buckingham, UK, Open University Press.

Cutts, Q., Kennedy, G., Mitchell, C., & Draper, S. (2004a): Maximising dialogue in lectures using group response systems. *Proc. 7th IASTED International Conference on Computers and Advanced Technology in Education*. Hawaii, USA 421-426.

Cutts, Q., Carbone,A., & van Haaster,K. (2004b): Using an Electronic Voting System to Promote Active Reflection on Coursework Feedback. *Proc. 10th Intnl. Conf. on Computers in Education 2004*, Melbourne, Australia.

Dufresne, R., Gerace, W., Leonard, W., Mestre, J., & Wenk, L. (1996): Classtalk: A Classroom Communication System for Active Learning. *Journal of Computing in Higher Education* **7**: 3-47.

Elliott, C. (2003) Using a personal response system in economics teaching. *International Review of Economics Education.* Accessed 11 Nov 2004 http://www.economics.ltsn.ac.uk/iree/i1/elliott.htm

Kennedy, G. and Cutts, Q.,The association between students' use of an electronic voting system and their learning outcomes. Submitted to *Journal of Computer Assisted Learning.*

Kolb, D. A. (1984): *Experiential Learning: Experience as the source of learning and development*. Englewood Cliffs, NJ, Prentice Hall.

Laurillard, D. (2002): *Rethinking university teaching: a conversational framework for the effective use of learning technology. 2nd Ed.* London,RoutledgeFarmer.

Mazur, E. (1997): *Peer instruction: a user's manual.* Upper Saddle River, NJ, Prentice-Hall.

Stewart, S., Brown, M., & Draper, S. (2004): Using an electronic voting system in logic lectures: one practitioner's application. *Journal of Computer Assisted Learning* **20**(2), 95-102.

Wit, E. (2003): Who wants to be… The use of a personal response system in statistics teaching. *MSOR Connections*, ***3***(2), 5-11.