

# Formative Teaching: A Conversational Framework for Evaluating the Impact of Response Technology on Student Experience, Engagement and Achievement

Samuel O. King, and Carol L. Robinson  
Loughborough University, S.O.King@lboro.ac.uk, C.L.Robinson@lboro.ac.uk

**Abstract** - There are two compelling constraints on the delivery of effective engineering mathematics education at university: Decline in the mathematical preparedness i.e. confidence and ability of engineering students, and the predominance of the passive learning-leaning traditional lecture mode of instruction. In this paper, we present a formative teaching paradigm, consisting of the use of specific question types and implemented via the use of Response Technology systems, whose adoption could help overcome these constraints. To evaluate the impact of this paradigm on student experience, engagement and achievement, we adopted a mixed-methods research protocol, consisting of multiple surveys, interviews, and observations. This evaluation process was guided by the application of the Laurillard learning model, designed for evaluating learning technologies. The evaluation results show that the paradigm facilitates *meaningful* behavioural and cognitive engagement, provides a richer and more learner-centred atmosphere, and contributes to a reduction in the number of students failing. However, the impact on student attendance and overall mean academic grades is negligible.

*Index Terms* - formative assessment, active learning, student experience, engagement, learning theory, evaluation, clicker.

## 1.0 INTRODUCTION

The ‘mathematics problem’ - the perceived decline in the mathematical confidence and competency of students, together with the reasons for the decline, has been well documented [1,2]. Compounding this mathematical ‘morass’ is the predominance of the traditional lecture mode of teaching in university classrooms, a mode which research shows is less than optimal for active learning [3,4]. To facilitate active learning in lectures, a number of research-informed practices, which are often technology-mediated, have been initiated [5,6]. These platforms are often implemented or mediated through the application of Response Technology (RT) systems, also known as clickers, electronic voting systems, et cetera. The ample literature on

RT systems indicates that their use could make lectures, especially in large classes, more interactive, facilitate higher student engagement, and increase participation [7-12].

In this paper, we present the results of an empirical study on the impact the use of the RT systems has had on student learning at an English university. The specific focus is on the use of the systems for the teaching of engineering mathematics (i.e. mathematics to engineering students) to two cohorts of second-year engineering students over the 2007/2008 and 2008/2009 academic sessions.

### 1.1 Background

The RT systems being used are the TurningPoint [13] radio-based electronic voting systems. These systems enable an instructor to poll students, and for student responses to be submitted live and anonymously. Student responses are subsequently displayed in the form of a suitable chart e.g. histogram, bar chart, et cetera – based on an instructor’s preference. The TurningPoint handsets are minimalist in design, durable and easy to use. However, only multiple-choice questions (MCQs), requiring alphanumeric responses may be used with the handsets (handsets allowing text-entry have been used in another context, but this is not the focus of this study). The handsets are not used to register or monitor student attendance, and questions are set for purely formative assessment purposes – assessment is therefore not graded. Further, students do not have to purchase the handsets. Students collect the handsets at the beginning of a lecture and hand them over at the end.

### 1.2 Research Questions, Significance and Outline

This study was designed to answer the following research questions: **(I)** What is the impact of RT on student engagement and experience of learning mathematics? **(II)** What is the impact of RT on student achievement, and the role of feedback in the learning process? **(III)** How may the Conversational Framework, Laurillard’s learning model [4] be applied to the evaluation of the impact of RT use?

The specific research contributions of this paper include: **(I)** An evaluation of the impact of RT use on student learning in mathematics through the application of the Laurillard’s conversational framework; **(II)** Highlight of the relationship between RT use and student academic performance; **(III)** An evaluation of the impact of RT use on specific components of student experience and engagement.

The outline of this paper is as follows: Section 1 is the Introduction; Section 2 describes the methodological procedures adopted for this study; and Section 3 describes the formative teaching paradigm. Section 4 presents the application of the Laurillard theoretical framework to the evaluation of RT usage impact, and this framework helps to theoretically contextualise the results presented in Sections 5, 6 and 7. Section 8 is the concluding section.

**2.0 METHODOLOGY**

A mixed-methods research protocol was adopted for this study. Reasons for this approach [14] include a need to ensure the validity and viability of results by designing the research around the use of multiple research methods, incorporating both quantitative and qualitative approaches. Further, a triangulation approach, defined as the use of more than one method to investigate a research question, was adopted. Third, a review of RT literature indicated that a major downside to the research conducted in this domain is the tendency to base findings on data collected from the use of one research method [8,9]. To make a meaningful contribution to the field, we felt that it was important that we anchor our data collection on a more rigorous research methodological platform.

*2.1 Sample*

This consisted of engineering students on a mathematics module. The students are second-year engineering students i.e. the penultimate year in the English system, and are typically adjudged to be, overall, above average academically, with a significant number having obtained an A grade in mathematics prior to admission to the course. This sample was selected for the study for two reasons [14]. First, one of the authors has been implementing the formative teaching approach with two cohorts of these engineering students over a two-year period. Second, another instructor who regularly uses RT had also taught students on this module in a first year class. The students are therefore not new to the use of RT, and it may therefore be expected that the Hawthorne Effect would have less of an impact on their perceptions of RT usage.

*2.2 Methods*

These consisted of a 13-question survey, consisting of a mix of open-ended and closed questions; a one minute questionnaire, based on the one minute paper concept [6]; semi-structured interviews with individual students; classroom observations of RT in use; a staff blog from

which we gleaned insights related to student learning, which subsequently informed the 13-question survey; and informal feedback from students and staff. The discussions in Sections 4 and 5 are based on research data from these methods, with student comments (in quotation marks) inserted where appropriate.

**3.0 FORMATIVE TEACHING**

This refers to the intentional design and creation of a learning environment where active student questioning and feedback is an integral part of the lecture experience for students in a class. Our approach is a variant of the Question Driven Instruction (QDI) paradigm [15], a variant because peer discussion is not a major goal – although students have often been asked to discuss their answers with their peers. A typical lecture might feature four to eight multiple-choice questions (Table 1), depending on the topic and the learning outcomes envisioned for that particular lecture. A critical component of this teaching paradigm is the readiness of the instructor to adapt the teaching, both in a particular lecture, and if required, for subsequent lectures, in response to feedback from student submissions to questions.

TABLE 1  
A DESCRIPTION OF THE RT-BASED QUESTIONS THAT HAVE BEEN USED FOR  
FORMATIVE TEACHING IN UNIVERSITY MATHEMATICS’ CLASSES AT  
LOUGHBOROUGH UNIVERSITY

<b>MCQ Type</b>	<b>Purpose</b>
<b>TEASERS</b>	To create a ‘light’ /relaxed atmosphere in class; For classroom management
<b>REVISIONS</b>	To identify student prior knowledge e.g. from first year mathematics course and; To highlight common student misconceptions e.g. about specific topics from previous instruction
<b>INTRODUCERS</b>	To introduce a topic - such that it gets student thinking in a different way than they are accustomed to about a particular topic
<b>APPLICATIONS</b>	To assess understanding of recently covered material
<b>CONCEPTS</b>	To assess conceptual understanding of a sub-topic deemed fundamental or one there is evidence students usually have difficulty understanding
<b>REPEATERS</b>	Repeat practice – the repeating of a question, which students found difficult at the first attempt, in a slightly varied mode to assess improvement in student understanding of the concept assessed in the initial question

In general, implementing the formative teaching paradigm requires:

- Redesign of the curriculum to identify the learning outcomes – this would, for example, include identification of the topics/sub-topics that

students routinely find difficult, common student misconceptions, incorporation of feedback from (previous) RT questions, etc. This is an iterative process within the formative teaching paradigm

- Creation and design of (good) questions – this should lead to the attainment of the learning outcomes by students. However, this is the most difficult part as creating really good questions takes considerable skill, time and (voluminous) practice [12,15]
- Adoption of an effective approach, based on teaching style preference(s) and theoretical ideology. It is possible to have two lecturers applying formative teaching, but with one more demonstrably effective in engaging students than the other, based on differences in delivery i.e. pedagogical content knowledge [16].

4.0 CONVERSATIONAL FRAMEWORK

The motivation for applying Laurillard’s Conversational Framework is to explain and illuminate, from a theoretical perspective, the factors that account for the observed impact of RT use on student learning [7,9]. Laurillard basically advocated that for learning to occur, there must be conversation or dialogue between the instructor and students. Further the theory has been specifically formulated for the evaluation of learning technologies [4,10,17]. The best way to illustrate the Framework is by showing how the different elements encapsulated in Figure 1 are achieved via the RT-enabled formative teaching platform. We would illustrate this with an example of a task set in class.

4.1 Application Context

**Task:** The task is the question, ‘Without integrating, evaluate  $\int_{x=2}^{x=4} \int_{y=1}^{y=3} 4dydx$

This task was given, via RT, in the first lecture of a mathematics module for second-year automotive/aeronautical engineering students; **Context:** Skill with relating double integrals to real world objects for conceptual understanding of the topics (volumes of solids, centres of mass, moments of inertia, et cetera) that the students, trainee engineers, would encounter on the module; **Task goals:** (I) To get students thinking of real world applications when they work with integrals; (II) To get students thinking throughout the whole module on how they could apply seemingly abstract mathematical constructs to solve problems in the discrete world; (III) To see how many students found the double integral difficult to evaluate because it had been observed, from previous teaching experience, that some students often struggled with relating it to the volume of a cuboid.

The ‘Teacher’s ideas’ represents instructor’s current Content Knowledge (CK) [16] and Pedagogical Content

Knowledge (PCK) of topic i.e. integration, while ‘Learner’s ideas’ represent current student understanding and prior knowledge of subject. The use of RT for polling students depicts the ‘practice environment’ while students’ engagement with answering the questions in class represents ‘Learner’s practice’.

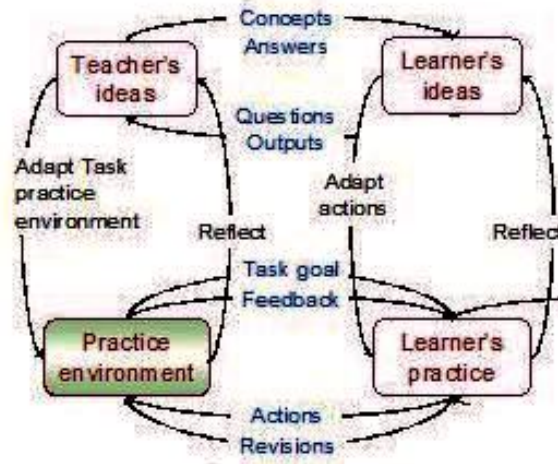


FIGURE 1  
A MODIFIED VERSION OF LAURILLARD’S CONVERSATIONAL FRAMEWORK FOR EVALUATING LEARNING TECHNOLOGIES [17]

4.2 Applying the Framework: Stage 1

The instructor creates and presents the question (task) based on current CK/PCK (Teacher’s ideas) to achieve the task goals identified above. The learner receives the instruction and thinks about working out the solution. This first step (especially if the task is changed from a question to be attempted in class to a worked example) occurs in most mathematics lectures at university.

4.3 Applying the Framework: Stage 2

**(I) Adaptation:** Before and whilst a learner is actually attempting the question - instead of making a mental note as is the case in the provision of worked example by instructor - s/he has to adapt the previous ideas held about the subject (in this case, always solving integration in a linear, decontextualised manner) in the light of the instructions provided, and the question’s demands. Hence this adaptation utility is absent in a typical lecture because there is no opportunity for students to practice on their own.

**(II) Practice:** This is when a student attempts the question by mentally processing the question, and this would require active and structured drawing on (learner’s) ideas and material presented in the lecture and/or instructions provided in order to arrive at a solution. This deliberate practice [3] helps reinforce targeted mathematical skills and identify gaps in knowledge and practice because it serves a diagnostic, self-assessment function. This principle is particularly poignant in mathematics because students learn largely by (thinking and) doing.

**(III) Reflection:** Question practice, the RT poll results and feedback from the instructor all help the learner in understanding where s/he went wrong and how to make the necessary amendments mentally and in practice. This reflection process in turn reshapes the learner's ideas about double integrals. Moreover, the teacher also gets feedback about students' performance in relation to the task goals, and this process can likewise refine the teacher's ideas about the subject.

### 4.4 Applying the Framework: Stage 3

To probe whether student proficiency and understanding about relating abstract formulas to real life objects (as in the task above) has increased in the aftermath of the task or lecture, an instructor could use a repeater (Table 1) or ranking and matching questions [12,15] to enable repeat practice so as to monitor student progress in a subsequent lecture.

## 5.0 STUDENT ENGAGEMENT

Research data from our study indicates that RT use has positively influenced the following components of student engagement:

**(I) Interactivity:** Three levels of interactivity have been observed during formative teaching: **(1) Surface Interactivity:** This is the interaction between student and instructor i.e. instructor poses a question which students respond to by answering, and which the instructor then responds to by providing feedback. This sets up a chain of interactivity between student and instructor, which is uncommon in contemporary university mathematics classes. But this occurs at the surface level because the mode of communication is limited, and mostly linear; **(2) Peer Interactivity:** This is the interaction between students. Class observations show that this interaction occurs when students compare their answers with their neighbours after voting, talk through a problem with a friend before voting, or in a limited sense, on the few occasions when the instructor asks the students to discuss their answers with their neighbours; **(3) Technical Interactivity:** This is the interaction between the system and the RT device – the students get to 'do something', even if that translates into merely clicking a handset. Further, this activity may help facilitate behavioural engagement, as described below.

**(II) Cognitive Engagement:** Students may appear attentive in class and be conscientiously copying notes, but this does not necessarily mean they are 'engaging' with the material [19]. But giving students questions to attempt in class tasks them mentally and requires them to recall and apply the facts and knowledge they have accumulated on a subject ("When you go through an example or we are taught something, you might be like; 'Oh I get that', but it's not until you do a question that you know whether you can or

not", "And it helps because we do questions very regularly, and it makes you – I feel like I can see where I need to put more work into, and where I can – don't have to put so much work into"). This deliberate practice [3] hence facilitates *meaningful* engagement [20].

**(III) Behavioural Engagement:** The use of RT systems facilitate student attentiveness in two ways: **(1)** Students have commented that because they know they would be tested on material presented in class, this has made them to consciously take cognisance of the material being presented ("In the lecture they ask you questions; make sure you've been listening"); **(2)** The time for polling also triggers student interest as students who might have been dozing or mentally 'checked out' of a class are 'retuned' into active learning mode because they have to be in a somewhat suitable mental state of preparedness to attempt the questions ("Keeps people awake and attentive during lectures"; "Stops boredom. Keeps people awake").

**(IV) Participation:** RT use for formative teaching very significantly increases student (in-class) participation, as measured by student submissions to questions via the RT anonymous usage mode [21]. This characteristic is important because English students, in contrast to their more expressive American peers, are usually taciturn in lectures and would not normally volunteer a response to a question posed by a lecturer.

**(V) Classroom Management:** Classroom observations show that the use of RT-based questions at specific time intervals inadvertently leads to the sequential delineation of lectures into discrete sections. This, among others, may help students recall a particular sub-topic in a lecture. This practice may also help focus student attention, as active student interest may only be sustained for a 15-20 minute period.

## 6.0 STUDENT EXPERIENCE AND FEEDBACK

**(I) Student Experience:** In this section, the impact of RT use on student experience, based on evidence from data obtained from the research methods adopted for this study, is briefly discussed: **(1) Attitude:** Most (i.e. 80%) of the students we polled, stated that they found RT 'useful' or 'very useful' [21] as well as overall advantageous, even after accounting for the drawbacks associated with RT use. This outcome is not surprising because attitudinal surveys on RT use have generally been consistently positive [7,10,11]; **(2) Fun:** Many students have used expressions like "it's fun so it helps make the class more fun" to describe lectures where RT has been used; **(3) Perception:** We conjecture that students see the RT devices as a tool that is there purposely to aid their learning, from a strictly altruistic purpose ("They add to the lecture more than anything"). This is because unlike some institutions where students are required to purchase the devices and where they are also used to register attendance which counts towards

the final grade for a module, the handsets are used with ‘no strings attached’; **(4) Novelty:** Some researchers have suggested that some of the affect features described above are due to the novelty factor. Although there is the Hawthorne effect to account for, we think that this effect is overstated because the current generation of students, as digital natives, is not overly impressed with RT devices [22]. RT devices are just another form of gadget for these technophiles.

**(II) Feedback:** Feedback in the formative teaching context achieves two goals from the learners’ perspective: First, it provides them with an understanding of the gaps in their knowledge of a subject (“You can tell yourself if you understand a topic”). Second, it provides them with knowledge of what to do to close the gap (“They [i.e. the lecturer] usually try and go through the solution afterwards, so most of the time, I just try to take in a bit more to make sure I can do it right next time”) [20]. From an instructor’s perspective, the most critical contribution of feedback is the provision of “information to teachers that can be used to help shape the teaching” [23]. Feedback also exerts a passive but beneficial influence on classroom dynamics. It has been observed that the atmosphere in the class ‘tends to rise’ when it is time for the solution to a problem to be discussed, especially if the question had been challenging.

**7.0 STUDENT ACHIEVEMENT AND RT USAGE DRAWBACKS**

**(I) Impact on Student Achievement:** A critique of research on RT impact on learning is the tendency for such research to mainly present findings on student attitudes or views of RT usefulness [8,9]. Therefore, a key goal of this study was to evaluate whether RT use has had any impact on student performance, as determined by mean student grades, attendance and retention. To do this, we compared the mean academic grades of three cohorts of students on a second-year engineering mathematics module taught by the same instructor over the 2006/7, 2007/8, and 2008/9 academic years – see Table 2. It should be noted that RT use was introduced in the 2006/7 session. Also, coursework was intentionally made more demanding for the 2007/8 and 2008/9 cohorts. Otherwise, the three cohorts are directly comparable, as course content and assessment modes remained unchanged across the three cohorts. The results (Table 2) show that there was no significant difference in the mean overall grades of the three cohorts. Observations of lectures also indicated that RT use did not have beneficial impact on student attendance.

However, the results show that student retention (i.e. significant reduction in the ‘% of students failed’) improved in the most recent year (2008/9). Although these results should be interpreted with caution, there is an indication that RT use, while having negligible impact on the overall grade, may help improve the scores of weaker students [24]. Research evidence also indicates that benefits from technological intervention in the classroom often start to appear from the second year of implementation [25].

Moreover as instructor skill and confidence with using RT in the formative teaching mode increases, this could be expected to somewhat impact student performance [12,18,24].

**(II) RT Usage Drawbacks:** Some of the limitations of the formative teaching paradigm include: **(1) MCQs:** These may encourage guesswork, so it becomes more challenging to ascertain what students really know and further, the efficacy of the use of MCQs for obtaining unbiased feedback may also be compromised by the inadvertent introduction of the “preconceptions of the questioner” [11]; **(2) Time:** It takes time to create good questions and to become proficient in the use of RT systems in lectures which have been adapted for formative teaching. Some instructors have also expressed concerns about their ability to cover the curriculum [26]; **(3) Poor Usage:** Using questions that are poorly designed is counterproductive to learning [12,15] (“Some questions are pointless”); **(4) Accessibility:** Issues regarding accessibility for individuals with visual impairment, dyscalculia, et cetera require investigation; **(5) Technical:** Malfunction of RT software and/or hardware.

TABLE 2  
DATA SHOWING THE ACADEMIC PERFORMANCE OF STUDENTS ON A SECOND-YEAR ENGINEERING MATHEMATICS MODULE OVER A THREE-YEAR PERIOD

COHORT CHARACTERISTIC	2006/7	2007/8	2008/9
NO. OF STUDENTS	145	147	156
COURSEWORK AVERAGE	81.3	58.9	64.7
EXAM AVERAGE	59.2	62.0	58.4
OVERALL AVERAGE	63.2	60.3	59.7
% OF STUDENTS FAILED	13.8	14.9	7.7

**8.0 DISCUSSION AND CONCLUSION**

This paper has described the use of RT to address the imperfections of the traditional lecture mode as well as to deepen the mathematical skills of engineering students via the formative teaching mode. Specifically, we presented the results of an evaluation of the impact of RT use on student experience and engagement, feedback in the learning process, and the application of learning theory for interpreting the results. The outcomes indicate that RT use has enriched student experience, facilitated greater student engagement, and created an effective feedback system between instructors and learners. However, we also enumerated a number of drawbacks that are associated with RT use.

The use of the Conversational Framework (Laurillard model) to explain the formative teaching paradigm illuminated the iterative processes of adaptation, practice and reflection on teaching and learning that are an integral part of this paradigm. These processes together facilitate interactivity, cognitive and behavioural engagement (Section 5) as well as the associated impact on student experience and achievement (Sections 6 and 7). The

Application of the Laurillard model thus validated the results by showing how RT use engenders learning via the iterative processes of *adaptation* and *reflection* and interaction between teacher and learner.

The net results of these continuous adaptation, practice and reflection processes include: **(I)** More cognitively and behaviourally engaged students, immersed in a learning context underpinned by a richer student experience; **(II)** Learners with more advanced or practised skills, of both the procedural and conceptual types, depending on the task type (Table 1); **(III)** Teachers with enhanced and more comprehensive intelligence about their practice and how best to help learners; **(IV)** A more productive and effective learning environment where there is monitoring of learners' progress on a topic by topic (or subtopic) basis, and cogent integration of theory (learner's and instructor's ideas) and practice; **(V)** RT-mediated conversation in the form of teacher-student and student-teacher interactions, instead of the monologue that characterises much of traditional university mathematics lectures.

In conclusion, this study demonstrates that RT systems have the potential to enhance student learning, especially when deployed within an appropriate context e.g. formative teaching or peer instruction. The emergence of text-entry systems with enhanced functionality would further magnify their value for learning. Further, we concur that "response systems have changed the classroom" [12], and that macro evaluative studies e.g. causal research [2,27] should be undertaken to verify and/or validate the efficiency and efficacy of RT systems across varied institutional contexts. Such evaluative studies would also contribute to determining how best to deploy this teaching and learning tool in engineering education and other educational domains. Our future research on RT use would contribute to the proposed macro evaluative studies, as we would be investigating how RT systems are being embedded in the teaching and learning of (engineering) mathematics at selected universities in the UK and the US.

#### REFERENCES

- [1] Hawkes, T. and Savage, M. D. 2000. *Measuring the Mathematics Problem*. London: Engineering Council.
- [2] National Mathematics Advisory Panel. Department of Education. *Foundations for success: The final report of the National Mathematics Advisory Panel*. 2008. Washington, DC: USA.
- [3] Bransford, J. D., Brown, A., and Cocking, R. eds. 2000. *How People Learn: Mind, Brain, Experience and School*, Expanded Edition. Washington, DC: National Academy Press.
- [4] Laurillard, D. 2002. 2nd ed. *Rethinking university teaching: A conversational framework for the effective use of learning technologies*. London: RoutledgeFalmer.
- [5] Novak, G., Patterson, E., Gavrin, A. and Wolfgang, C. 1999. *Just-in-Time Teaching: Blending Active Learning and Web Technology*. Upper Saddle River, NJ: Prentice-Hall.
- [6] Angelo, T. A., and Cross, K. P. 1993. 2nd ed. *Classroom assessment techniques: A handbook for college teachers*. San Francisco: Jossey-Bass, pp. 148-153.
- [7] Caldwell, J.E. 2007. "Clickers in the large classroom: Current research and best-practice tips." *Life Sciences Education*, Vol. 6, pp. 9-20.

- [8] Kaleta, R., and Joosten, T. 2007. "Student response systems: A University of Wisconsin study of clickers". *ECAR Research Bulletin*, Vol. 2007, No. 10.
- [9] Simpson, V., and Oliver, M. 2007. "Electronic voting systems for lectures then and now: A comparison of research and practice." *Australasian Journal of Educational Technology*, Vol. 23, pp. 187-208.
- [10] Cutts, Q., Kennedy, G., Mitchell, C. and Draper, S. "Maximising dialogue in lectures using group response systems." In *7th IASTED International Conference on Computers and Advanced Technology in Education*, August 2004, Hawaii, USA.
- [11] Abrahamson, L. A. "A brief history of networked classrooms: Effects, cases, pedagogy, and implications". In Banks (ed.). 2006. *Audience Response Systems in Higher Education: Applications and Cases*. Hershey, PA: Idea Group Inc., pp. 1-25.
- [12] Boyle, Jim. "Eight years of asking questions." In Banks (ed.). 2006. *Audience Response Systems in Higher Education: Applications and Cases*. Hershey, PA: Idea Group Inc., pp. 289-304.
- [13] TurningPoint: <http://www.turningtechnologies.co.uk/>. Accessed: 10 September 2008.
- [14] Burton, L. 2002. "Methodology and Methods in Mathematics Education Research: Where is the why?". In Goodchild and English (eds.). *Researching Mathematics Classrooms*. Westport, CT: Praeger, pp. 1-10.
- [15] Beatty, I. D., Leonard, W. J., Gerace, W. J., and Dufresne, R. J. "Question driven instruction: Teaching science (Well) with an Audience Response System". In Banks (ed.). 2006. *Audience Response Systems in Higher Education: Applications and Cases*. Hershey, PA: Idea Group Inc., pp. 96-115.
- [16] Shulman, L.S. 1986. "Those who understand: Knowledge growth in teaching." *Educational Researcher*, Vol. 15, pp. 4-14.
- [17] Laurillard, Diana. "Evolving a Vision for Technology-Enhanced Learning." *Keynote Presentation, Networked Learning Conference*. May 2008. Halkidiki, Greece.
- [18] Crouch, C. H., and Mazur, E. 2001. "Peer instruction: Ten years of experience and results." *American Journal of Physics*, Vol. 69, pp. 970-977.
- [19] Hamilton, E. and Hurford, A. 2007. Combining Collaborative Workspaces with Tablet Computing: Research in Learner Engagement and Conditions of Flow. In *Proceedings of the 37th ASEE/IEEE Frontiers in Education Conference*. 11-13 October 2007. Milwaukee, Wisconsin. IEEE Press.
- [20] Black, P. and Wiliam, D. 1998. "Assessment and classroom learning". *Assessment in Education*. Vol. 5, pp. 7-74.
- [21] King, S.O. & Robinson, C.L. (in press). "Pretty Lights' and Maths! Increasing Student Engagement and Enhancing Learning through the Use of Electronic Voting Systems." *Computers & Education*. <http://dx.doi.org/10.1016/j.compedu.2009.01.012>.
- [22] Butler, Melanie. 2005. "What I Learned from...Using a Personal Response System". <http://www.maa.org/features/021405wilperresp.html>. Accessed: 3 September 2008.
- [23] Nicol, D., and Macfarlane-Dick, D. 2006. "Rethinking formative assessment in HE: a theoretical model and seven principles of good feedback practice". [www.heacademy.ac.uk/assets/York/documents/ourwork/tla/assessment/web0015\\_rethinking\\_formative\\_assessment\\_in\\_he.doc](http://www.heacademy.ac.uk/assets/York/documents/ourwork/tla/assessment/web0015_rethinking_formative_assessment_in_he.doc). Accessed 10 October 2008.
- [24] Boyle, Jim, Nicol, David, Hamilton, Bobby, and Dempster, Bill. "The Use of Classroom Feedback Systems to Enable Active Learning in Large Engineering Mechanics Classes". In *The International Conference on Engineering Education*. 2001. Oslo, Norway.
- [25] Somekh, B., Haldane, M., Jones, K., Lewin, C., Steadman, S., et al. 2007. *Evaluation of the Primary Schools Whiteboard Expansion Project*. Coventry: Becta-DFES.
- [26] King, S.O., Davis, L., Robinson C.L., and Ward, J.P. 2008. Use of Voting Systems in Lectures at Loughborough University – A Review of Staff Experiences. In *Mathematical Education of Engineers Conference*. April, 2008. Loughborough, England.
- [27] Sloane, Finbarr C. 2008. "Randomized Trials in Mathematics Education: Recalibrating the Proposed High Watermark." *Educational Researcher*, Vol. 37, pp. 624 - 630.