Paper

ARCHITECTURE FOR ACTIVE AND COLLABORATIVE LEARNING IN A DISTRIBUTED CLASSROOM ENVIRONMENT

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Abstract

The goal of this research is to develop a web based architecture that facilitates active learning in the classroom environment as well as provide support for collaborative problem solving. To accomplish this goal, we have developed an Active and Collaborative Learning System (ACLS). By using ACLS architecture, the students who are in different locations are encouraged to respond (in an anonymous way) to a set of questions associated with the lecture topics using one of the devices such as remote controls (clickers), cell phones, PDAs, or laptops. Our system collects students' responses and makes it available immediately to both instructors and students. By looking at these results, the students can know where they stand with regard to their knowledge of a particular topic as well as where they stand in the class. Also, the instructors know if more elaboration on a particular topic is required. When necessary, our system allows for collaborative problem solving in a distributed environment. For example, when a group of people who are distributed across the campus are working towards solving a complex problem the interactions are supported by the framework.

Key Words: Active learning, Clickers, Hybrid architecture, Student feedback, Collaborative learning.

1. Introduction

Active learning is a learning approach in which the students are actively involved in the learning process as opposed to passively observing the lecturers [1, 2]. This process encourages students to ask questions and provide answers during the lecture and puts the students in a reflective mode, which helps the students to internalize the concepts taught and possibly engage in an in-depth discussion. In addition, active learning helps the learner to focus on specific objectives. It helps the students to receive feedback on misunderstood concepts [1]. It also provides opportunity for repetition.

Research has shown [2-8] that the usage of clickers in the classroom has helped the students in focusing and being more involved in the topics discussed in the lectures.

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Clickers are miniature “TV remote control” look-alikes (Fig. 1), which students can bring along to the lectures [9, 10]. The lecturer can pose questions during the middle of the lecture to find out if the students are following what he/she has said. The students press one of the keys corresponding to the multiple-choice answers displayed using their Clickers [10].

By getting an immediate feedback, the students can gauge their understanding and strive to improve their knowledge of the topic. Also, by having knowledge of how other students are doing, the students can be positively stimulated and challenged in attempting to improve their knowledge.

FIGURE 1 – AN INFRARED CLICKER [9]

The clickers can be of use in a variety of ways. Firstly, it provides feedback to the lecturer about students’ understanding. As the feedback is anonymous, the students are at ease and more willing to participate in the class unlike raising their hands during the class. The results can be displayed as a histogram as shown in Fig. 2.

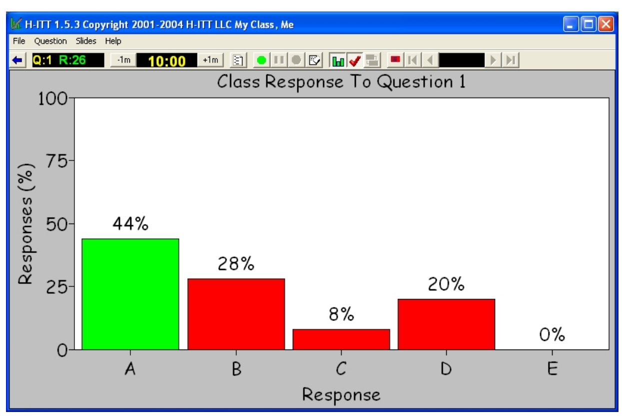

Figure 2 – Histogram showing student responses [9]

Since clickers can be expensive for the students to purchase , it is desirable to use the students’ existing resources such as cell phones, Personal Digital Assistants (PDAs) etc. which provide clicker like features with more capabilities such as sending text data to the server. These devices can also be used to facilitate collaborative learning environment such as laboratories where students interact with each other while trying to solve a problem.

In this paper we discuss our framework that supports active learning by providing flexible options to the student with regard to his/her selection of the device to be used for classroom interactivity. Our framework will support distributed classroom learning. Our framework also provides support for collaborative problem solving in a distributed classroom environment.

2. Related Work

The concept of Clickers dates back to the work done by Prof. Raphael Littauer, at Cornell University in 1971. Each student had a chair and the chair's armrest was embedded with a clicker like hardware, which was connected to a computer, which processed the responses.

Using student response systems in the classes and its effects have been studied by many researchers [2-7]. Most researchers [2-5] have found that the student response systems have made their classes more effective. They have also reported an increase in student attendance and performance. A larger study carried out by Ebert-May [5] observes that students who have experienced active-learning using student response systems had significantly higher self-efficacy and process skills than the students learning in a traditionally taught course. The students also had higher confidence in explaining subject matters to other students in practical sessions (Example: Biology practical session).

Inspired by Lowery's work [9] we have categorized the devices used in the interactive learning system (ILS) into five types as shown in Table 1. The first type of the system consisted of hard-wired environment as was discussed earlier. Due to advancement of technology these systems were replaced with second type of devices that used Infrared. The difficulties caused by the line of sight problem with the Infrared devices led to the development of third type of devices that used radio frequency. These devices are more portable and easier to use. However these devices had limited capabilities and led to the usage of fourth kind of devices, which were more powerful such as cell phones and PDA's and laptops. These devices enabled the Web-based distributed interactivity. Due to increase in the uptake of the cell phones and widespread acceptability of the infrared devices already present in the market, it is desirable to build a framework that enables the co-existence of these technologies.

In this paper we describe a fifth type of system which is a hybrid system in which Infrared and web-based technologies can co-exist. Other researchers are working on similar web-based systems for enabling clicker like technology [10].

Table 1: Types of student response systems and their features.

Type	**Technology**	**Device Features/Capabilities**
Type 1	Hard wired systems	1. Customized client hard-wired to a centralized server 2. Basic clicking support, fixed location of devices
Type 2	Infrared Clickers (TV remote control like devices)	1. Portable devices that require line of sight
Type 3	Radio waves (Ex. WIFI) - TV remote control like devices	1. Portable devices that do not require line of sight
Type 4	Web-based	Cell phones, PDAs, Laptops, Distributed (Intranet or Internet based)
Type 5	Hybrid architecture	Integration of Types 1 to 4 (Type 4 and any proprietary systems that belong to types 1 to 3)

Our work is unique, since we have also incorporate collaborative learning and problem solving mechanism in the hybrid architecture. The concept of collaborative/cooperative learning [11, 12] has been widely researched and advocated across the literature. The term "collaborative learning" refers to an instruction method in which students at various performance levels work together in small groups towards a common goal. Collaborative learning provides a mechanism that reinforces the group members' knowledge and understanding. It has been observed that collaborative learning helps the participants to create a better quality output due to peer review and evaluation. It helps to develop a positive team spirit and also improves the communication skills. Our hybrid architecture can help students to collaborate in a distributed environment (described in section 4.2).

3. Our experience with the Clickers

We have explored the advantages of using the clicker technology in two of our courses. We have used the clickers in a large classroom of 90 second year students and also in a smaller class of 20 third year students in 2005. The students' feedback on using these remote controls in the classes is encouraging. The outcome of using the clickers is described as follows:

3.1 Increase in student focus on the topic taught

The students were aware that they would be asked to answer questions from time to time. This enabled them to concentrate on the topic that was being taught. Research suggests that the student retention time is usually 15-20 minutes. In order to maintain the students' focus, we posed questions in regular intervals of time. We found that 77% of the students using the clicker technology answered to the question "*It was easy to focus your attention on material being covered in class (for example the Clickers could have helped from falling asleep or avoiding 'day dreaming').*" positively.

3.2 Increase in active participation

Due to the fact that the responses were treated anonymously the students were more willing to participate. Also because of the peer pressure with the regard to where they stand in the class, the students are keener to get involved in the process. When the students were asked "*You find it interesting to see how others answer or feel about a topic and you are able to find immediately where you stand in the class*", 92% of the class had a positive response.

3.3 Enabling an adaptive approach to teaching

Due to the immediate student responses, the lecturer is able to adapt to the needs of the students by elaborating on those topics that the students require more explanation. This approach enables the lecturer to make the learning process more student centered. This has also been supported by other researchers [4].

3.4 Continuous student feedback

Usually teachers assess their teaching effectiveness once or twice during the academic year/semester in which the course is taught. Using the clicker technology enables the possibility of obtaining student feedback periodically as desired by the teacher. The students can be asked to provide feedback on the various aspects of the course, such as the coverage of the topics, structure of the course and so on. These feedback can then be used to improve the course appropriately.

3.5 Increase in motivation for more in depth discussion

The enquiry-based teaching facilitated by the clickers increases the analytical and probing ability, which leads to a more in-depth discussion in the class, as well as outside of the class. In our course, we used an on-line discussion mechanism supported by the instructional support software, BlackBoard [13]. In a semester course of 90 students, we had 1500 postings. We believe these discussions clarified certain common misunderstandings. It also created a learning community in which the students shared both their understanding and their problems.

3.6 Increase in student attendance

Due to the positive impact of using the clickers which is attributed to the fact that the students play an active role, they are more eager to attend and be challenged in the class. In order to facilitate better feedback concerning the knowledge assimilated so far and to examine students' ability to synthesize related concepts, we conducted pop quizzes every four weeks. Another benefit of these quizzes was the improvement in student attendance. Some researchers have come up with a mechanism to encourage student attendance based on the participation of the students using the devices [14].

3.7 Increase in student satisfaction

Most students indicated that the course was made more enjoyable due to the use of the clickers. When the students were asked "*The Clicker makes the course more enjoyable than the courses that do not use this technology*", 80% of the students answered favorably.

3.8 Automatic student assessment

Certain vendors of this technology provide mechanisms [15, 16] for automatic assessment of the student quizzes and easier integration with the BlackBoard for displaying the results to the students. Our students noted that they were happy to see their quiz marks uploaded immediately after the class.

3.9 Increase in students understanding

When the students were asked "*You feel that the clicker questions help you test your understanding and make you think more about important points covered on a particular topic*", 89% of the students felt that clickers helped them to understand the concepts by making them think about the concept that had been taught.

3.10 Other benefits

Similar to other researchers [1], we have used Clickers to assess students' understanding of the reading assignments that they were expected to complete before coming to the class. Clickers were also used for opinion surveys, such as choosing a class representative and immediate teaching evaluations.

3.11 Limitations

A limitation of the clicker technology is that the user can choose only one of the options (multiple choice type questions with a set of options such as A, B, C, D…) available on the remote control, and there is no way to key in a textual answer. So the questions that are posted should be of multiple-choice type.

3.12 Recommended technological improvements

To improve the current technology, several enhancements can be made, such as the incorporation of a richer input and output capability and maintaining and displaying the accumulated score to the student. There is a need for developing an alternative architecture which integrates student resources, such as cell phones or PDA's, with the clicker technology where the students have the choice of using cell phones or buying a clicker. The prototype architecture and the additional enhancements to this technology which enable collaborative learning, are discussed in the next section.

4. Architecture

The first objective of this architecture is to integrate heterogeneous technologies, such as WIFI [17], infrared [18] etc. associated with distributed learning environment. The second objective of this research is to facilitate a collaborative learning environment. Consider the scenario where students attend a lecture where they are engaged in learning a particular concept. In this context, they are interacting with the teacher by submitting their responses to the questions posed by the teacher using a cell phone or a PDA. The lecturer now poses a more complex problem to the student and allows them to collaborate in the classroom. This leads to more discussion in the classroom. Also, the students can work collaboratively outside the classroom using our framework. This framework allows students to send questions, solutions, comments etc. to each other.

4.1 Hybrid architecture of the module that integrates the heterogeneous technology

In this section, we describe how we achieve the first objective of designing and implementing a hybrid web based architecture.

The hybrid architecture of the system is shown in Fig. 3. The students can use the browser in their cell phones, PDA's and laptops to connect to the classroom performance server. Alternatively, the students can also use infrared clickers. The classroom performance system server collects data from all the clients. The results will be then sent to the instructor's laptop, and this information can be displayed to the local students using a data projector. In a teleconferencing scenario the results will be displayed through the teleconferencing tool that is being used.

4.1.1 CPS server

The Classroom Performance System (CPS) server comprises modules for the collection of data from different devices:

a) Infrared

b) Cell Phones/PDA's/Laptop's that use WAP [19] over WIFI

c) Cell Phones/PDA's that use WAP over GPRS [20]

It also integrates data obtained from disparate sources and stores it in a persistent storage. It also provides modules that provide interfaces so that the clients can query data using various options. The server has been implemented using Java's web technologies (JSP, Servlets and JDBC) [21].

4.1.2 Lecturer's laptop

The lecturer's module collects the infrared clicker data and sends this information to the CPS server. It also queries the CPS server and displays the data to the user in textual and/or graphical format on a data projector.

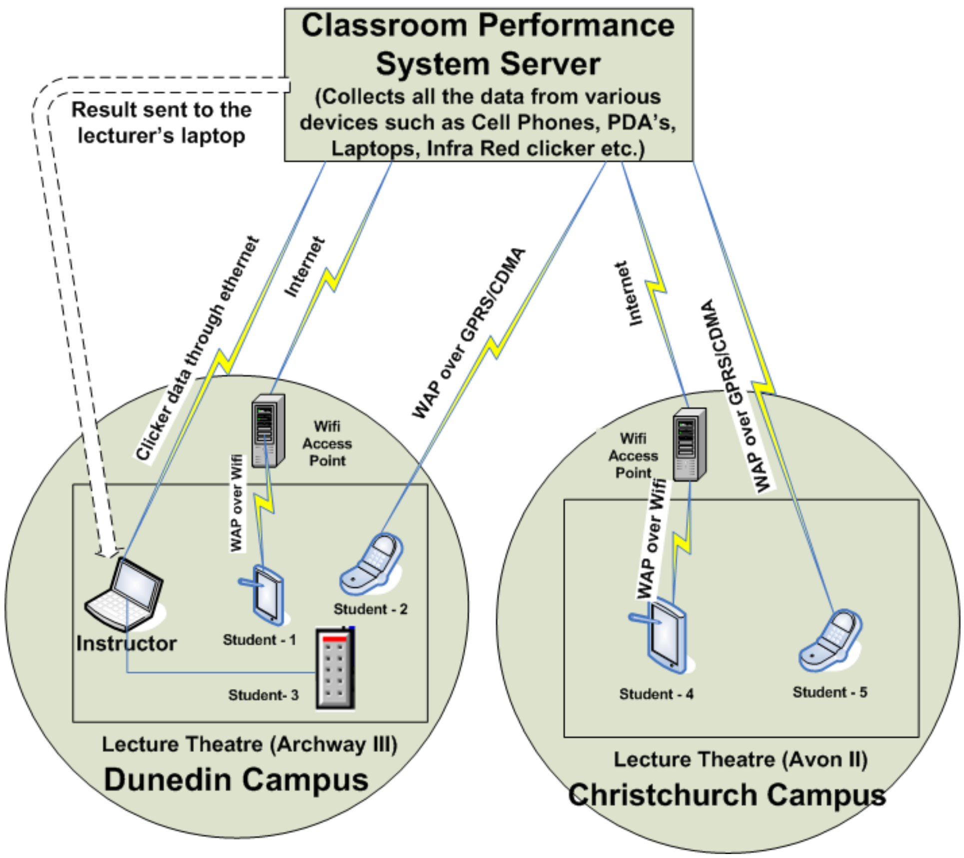

Figure 3 – Hybrid web based architecture of the Active and Collaborative Learning System (ACLS)

4.1.3 Student devices and the gateway servers

The student can either use clickers or cell phones, PDA's, laptop. When using the latter devices, they connect to the CPS server using a specific URL for submitting their answers and viewing the feedback (acknowledgement and scores). While using WIFI or Bluetooth [22] in their devices, they are connected to the Internet using an appropriate local gateway server.

4.1.4 Issues related to use of cell phones

Some researchers are concerned that using cell phones may distract the students and the lecturer when a call interrupts the lecture. Although this could cause problems, we believe there are mechanisms for the students to redirect the phone calls while attending classes using the facilities offered by the mobile service provider. Our initial effort to confirm this approach was successful when we contacted a major telecommunication provider in New Zealand.

4.2 Module that facilitates collaborative learning architecture

In this section, we describe our second objective which demonstrates how students can use smaller devices to aid their understanding and to solve problems in the classrooms, laboratories and the campus environments.

This module will achieve the following:

1. Enable students to submit an answer to the question posed by the lecturer in the classroom
2. Provide the students a collaborative learning environment to interact with other students (say in a library or in the university campus) to solve problems.

This scenario can be best understood by Fig. 4, in which we use Coloured Petri Net (CPN) notation to represent the workflow models. Petri nets consist of four basic elements:

- the places (circles) that are typed locations that can contain zero or more tokens,
- the tokens (usually dots placed inside the places, not shown in this Fig. 4) which are typed markers with values
- the transitions (rectangles) which represent actions whose occurrence can change the number, locations and value of tokens in one or more of the places connected to them, and
- the arcs (arrows) and their inscriptions that connect places and transitions.

A detailed description of CPNs can be found in [23].

The model shown in Fig. 4 represents the students' side of the instructor-student interaction that takes place by means of the system. These models represent the overall interaction that could take place between the student and the lecturer. As shown in Fig. 4, the student can receive question from the lecturer or send a question to the lecturer. Once the question is received, the student can submit the answer or ask for a hint from the teacher. The student can also receive answer for the question that was posed. The student can then receive the assessment for the question that he/she answered.

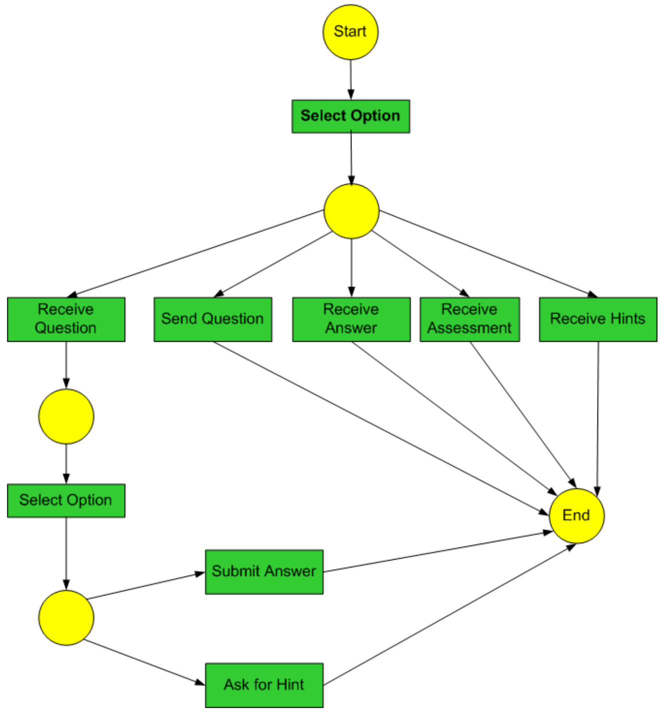

Figure 4: Process model for student interactions

Fig. 5 shows the process model of the instructor-student interaction from the instructor's side. In this model, in addition to sending questions and receiving a response, the instructor may evaluate student responses and send appropriate feedback and the outcome of assessment.

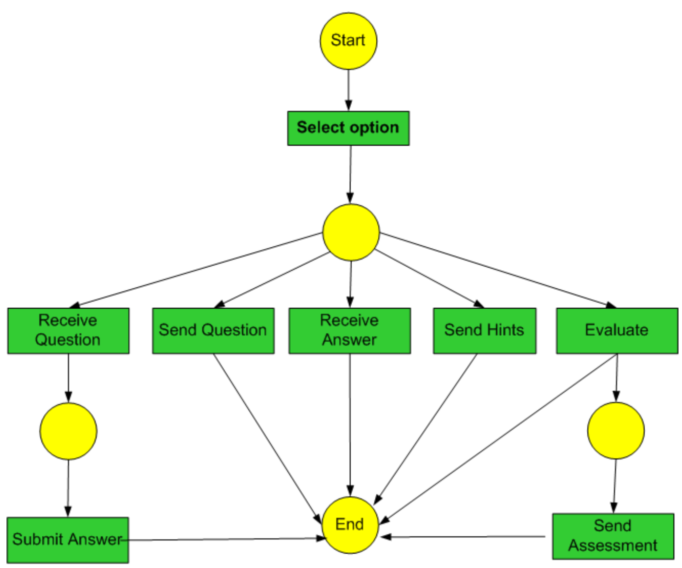

Figure 5: Process model for instructor interactions

Fig. 6 shows the pictorial view of two PDAs and a cell phone in action during a session that involves three students while solving a problem collaboratively. The framework supports the messaging between the interacting partners.

4.2.1 Implementation details

To support the collaborative work, we have used the Opal [24] system, which provides infrastructural support to create agents that represent each collaborator. This framework enables the communication mechanisms required for students to interact with each other by sending agent messages and Interaction Protocols [25] represented schematically by Fig. 4 and 5. Each collaborator agent has a Petri net engine JFern [26] which executes its specific interaction process model.

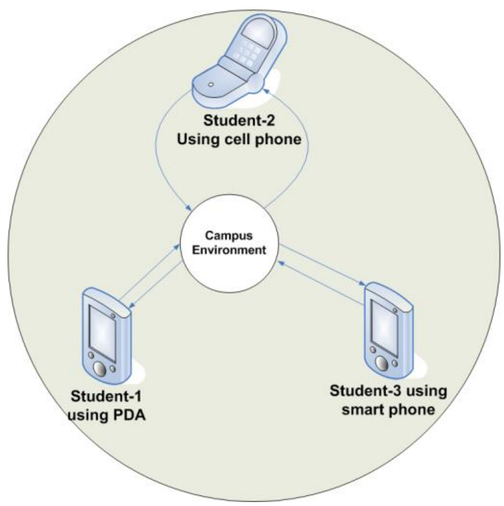

Figure 6: A collaborative problem-solving scenario

The conversation manager as shown in Fig. 7 is the component within an agent that organizes the interaction between various agents that represent the students and instructors. It is responsible for dispatching the messages from the *Start* and *End* places. For example when a student asks a question, the message is put in the *End* place of the student model. The student's conversation manager then removes this token from the *End* place of the student model by means of inter-agent communication and sends it to the instructor's agent. Upon the receipt of the agent message from the student by the instructor agent's communication module, the instructor's agent conversation manager in turn, causes the appropriate message to be placed in the *Start* place of the instructor's model. The instructor can then respond appropriately using the same mechanism. Similarly, student-to-student collaboration is possible using this mechanism. The conversation manager will keep track of all the students using unique ids.

Currently the collaborative learning module of the hybrid architecture is implemented to work on high-end computing devices (workstations) available in the student laboratories. We are working on porting this application to smaller devices (PDA's and smart phones) so that the students will have more flexibility to interact with each other and the lecturer from anywhere on campus.

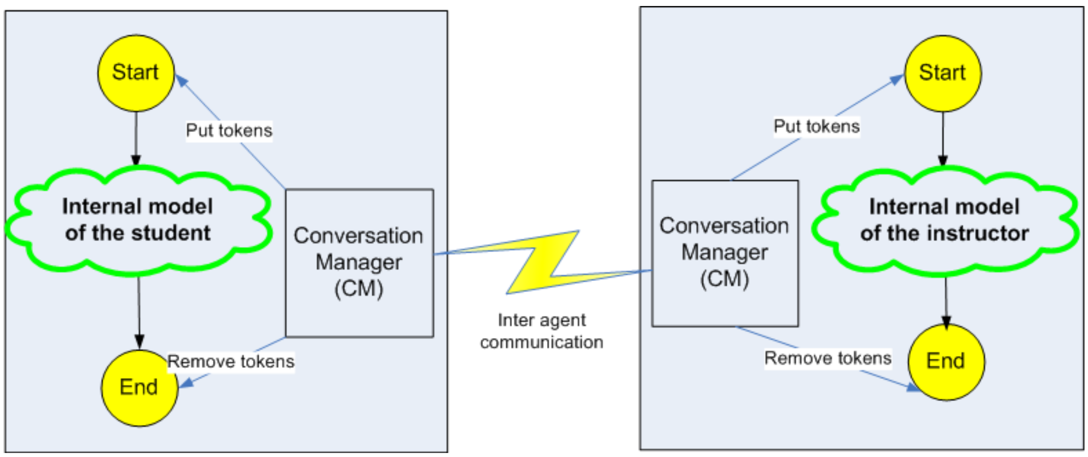

Figure 7: Student-Teacher interaction mechanism.

4.3. Evaluation of the hybrid architecture

Based on the evaluation provided by R. Lowery, our framework meets all the criteria specified. In addition it also caters for a distributed and collaborative classroom environment, which is capable of supporting various devices with richer input/output capability. The comparison of Active and Collaborative Learning System (ACLS) with the existing systems is presented in Table 2. A tick mark (√) indicates the support of a particular feature and a hyphen (-) indicates the unavailability of a particular feature.

Our hybrid architecture supports two-way feedback to the clients where an acknowledgement is sent to the student upon the receipt of the answer. The users can also enter text input for certain questions (when enabled by the lecturer). This architecture can support both face-to-face lecture sessions, as well as distance taught lecture sessions. Our architecture can be used in conjunction with other technologies (Ex. H-ITT) [9]. Since our system is web-based, this can be used on any operating system and can support a variety of communication modes such as Infrared, Bluetooth, and WIFI.

We are aware of other potential alternative clicker technologies, such as pattern recognition of paper based student response systems, open clicker project [27] etc. Because these systems are still in their infancy we have not included them in our evaluation.

Table 2: Comparison of existing clicker technologies with ACLS

Features	**eInstruction's CPS**	**HITT**	**PRS**	**Turning point**	**Project Numina II**	**ACLS**
Two-Way feedback	√	√	-	√	√	√
Text input/output	√	-	-	√	√	√
Support for distributed classrooms	-	-	-	-	-	√
Support for collaborative learning	-	-	-	-	-	√
Integration with other technology	-	-	-	-	-	√
OS compatibility						
1- Windows	√	√	√	√	√	√
2- Mac	√	√	√	-	√	√
3- Linux	-	√	-	-	√	√

Conclusions

Inspired by the work done by the researchers in the field of active learning and by our own experience in using interactive clicker tools in the classroom, our research focuses on building a hybrid architecture that makes use of available student resources while making use of existing clicker technologies. The architecture that we have developed can be used in distributed environments, such as the distance learning classrooms. We also compare our architecture with the existing systems available on the market and explained how the system can be used for collaborative problem solving.

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