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Designing a Mobile-app-based Collaborative Learning System

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Executive Summary

An important aspect of education is to promote higher-order thinking skills to learners. However, in the lecture environment, learners are passively engaged and it is unlikely for higher-order thinking to occur. Although interventions such as "clickers" can be used to increase engagement in lectures, this does not necessarily promote higher-order thinking. Approaches such as collaborative learning are better suited for this but there is little room to use such methods in the short time frame of a lecture.

With recent advances in the capabilities of smart mobile devices and their growing penetration rate among the student cohort, it is possible to take advantage of these devices to design a system to promote higher-order thinking skills in the lecture environment.

We present the design of a mobile-app-based collaborative learning system named *myVote* and a process for its usage. Our aim is to present a theoretical paper that discusses the relevant learning theories used in designing the system as well as describe a process to use the system to achieve collaborative learning at varying levels of thinking.

We demonstrate the usefulness and flexibility of the system through three scenarios involving different levels of thinking, ranging from lower- to higher-order. Although the scenarios are in the context of IT education, the system is versatile enough to be adapted for education in general and also non-educational settings, such as business-like environments.

Our contribution is a framework for using mobile apps and collaborative learning theories within a lecture environment to encourage higher-order thinking in learners.

Although a potential limitation of the system is that it may not be appropriate for teaching more technical IT materials, such as programming and SQL code snippets, the problem can be re-casted in a different format such as pseudocode in order to facilitate teaching in these areas.

Keywords: higher-order thinking skills, collaborative learning, smartphones, computer-support collaborative learning, Delphi survey, mobile app

Introduction

Collaborative learning is a group-based learning approach in which learners are mutually engaged in a coordinated fashion to achieve a learning goal or complete a learning task (Dillenbourg, Baker, Blaye, & O'Malley, 1996). Collaborative learning centers on a social

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constructivist approach in which learners are in charge of their own learning and engage socially to construct knowledge. Collaborative learning can increase learner engagement (Gokhale, 1995) and promotes higher-order thinking, such as critical thinking.

Collaboration technologies are typically used to support group collaboration, however, they can be adapted to support collaborative learning. This nexus between collaborative learning and collaboration technology is related to computer-supported collaborative learning (CSCL), in which technology is used to support or better enable collaborative learning.

Technology has the potential to improve many aspects of our daily lives, including learning. It has been proven to increase student engagement (Kuh & Hu, 2001) and learning outcomes. However, as current students are very technology savvy, and are getting more so with each generation, in order to engage them with technology, educators must use the same up-to-date (if not bleeding edge) technologies that students are already using. Additionally, the technology must be used in the same (or in a compatible) manner in which students use them. This leads to a smoother uptake and better acceptance within the student cohort.

The proliferation of smart mobile devices, such as smartphones and tablets, make them an obvious choice of technology with which to engage students. These devices are no longer just the voice communication devices of the past. They are now universal and mobile computers carried around by most students, most of the time and impact in almost every aspect of their lives, including university. Newer generations of students who have lived with such technologies for the greater majority, if not all, of their lives, are passionate and dedicated users of such smart mobile devices. In particular, these students enjoy the connectivity and social interaction which occur from the use of these devices and prefer group-based activities (Cobcroft, Towers, Smith, & Bruns, 2006).

The traditional lecture, in which an instructor conveys knowledge to a group of learners within limited time, is a common form of teaching despite its limitations. One significant limitation of the lecture is that students are passively engaged in learning. Although a number of activities have been used to more actively engage learners in such settings, many of these activities do not promote higher-order thinking unless they are extensive, such as a whole class discussion or analysis of case studies. They are time consuming and not typically feasible within the short time frame of a lecture. An example is, “think/pair/share”, in which students summarise the lecture material to another student sitting next to them and then to the entire class (Silberman, 1996). A technology-driven example is a system which can be used to poll the audience, colloquially known as “clickers” or more formally as personal response systems, classroom response systems, student response systems, audience response systems, or class communication systems (Beatty, 2004; Caldwell, 2007; Fies & Marshall, 2006). Clickers are small mobile devices used by students to respond to a multiple-choice question posed by the lecturer. They can be used to better engage students in lectures (Beekes, 2006); however, they do not inherently promote higher-order thinking skills.

The development of higher-order thinking skills is an important outcome of education. Academic achievement is not simply about academic grades, but also the development of higher-order cognitive abilities such as critical thinking and problem-solving. Higher-order cognitive processes are desirable as engaging in them leads to active learning (Bonwell & Eison, 1991), which facilitates knowledge construction on the part of the learner (Meyers & Jones, 1993).

Technologies normally used to support collaborative learning, and hence higher-order thinking, such as online discussion forums, blogs, and wikis, are not practical for in-class activities in lectures. However, the benefits resulting from collaborative learning are desirable, especially in lecture-like settings where this approach can better engage students.

We present a theoretical paper to discuss the design of a mobile-app-based collaborative learning system to promote higher-order thinking skills in lecture-like settings. Since lower-order thinking, such as knowledge recall and comprehension, provide a foundation for higher-order thinking, the system should be versatile enough to support both lower- and higher-order thinking. Our contributions includes a framework for designing the system taking into consideration the relevant learning theories and a description of the process used to achieve higher-order thinking skills in teaching sessions of limited durations and interactions, such as the lecture environment. We also illustrate the usage of the system to achieve various levels of thinking through a range of scenarios.

Background

Students seem to learn better or solve problems correctly when they collaborate with others, especially when the task is conceptual or complex (Gabbert, Johnson, & Johnson, 1986). Furthermore, collaboration among students also seems to have beneficial effects such as improving social relations or increasing motivation (Sharan, 1980).

In this section, we discuss the relevant collaborative learning theories, the technologies to support collaborative learning, and mobile learning applications.

Collaborative Learning Theories

Collaborative learning is an umbrella term that covers a range of approaches in which learners achieve an academic goal together. It is a shift from traditional teacher-centered approaches to contemporary learning approaches, including student-centered, social learning, active learning, and constructivism (Kirschner, 2001).

Collaborative learning has a number of benefits when compared to individual learning. It enhances critical thinking in learners (Gokhale, 1995). Critical thinking generally refers to the ability of making reasoned judgements and autonomous thinking (Paul & Binker, 1993) and also having metacognitive awareness and problem-solving abilities (McLoughlin & Luca, 2000). There is also evidence that collaborative thinking encourages learners to take ownership of their own learning (Johnson & Johnson, 1986) and to retain information longer compared to individual learning (Totten, Sills, Digby, & Russ, 1991).

In a study of problem-solving teams, team performance was found to depend on team interaction since members of successful teams engaged in each other’s thinking while members of low performing teams ignored each other’s solutions (Barron, 2003). However, the benefits of collaborative learning are not universal and seem to vary across learning tasks and individual students (Tudge, 1989).

Social interaction is the key variable in collaborative learning and a number of theories provide philosophical support for its importance. According to Vygotsky’s social learning theory (1978), social interaction plays a fundamental role in the development of cognition of an individual since knowledge is constructed through interaction with others (social constructivism). Habermas’ theory of communication action indicates that meaning emerges interactively (cited in Garrison, 1992) while Garrison (1992) suggests that meaning is created through communicative actions. Psychologists believe that there is a clear link between critical thinking, social interaction and deep learning since cognitive skills are developed in a social context (Newman, Webb, & Cochrane, 1995).

In order to create a learning community in which learners share common values and actively engage in learning with each other, several conditions must be met. A collaborative workspace must be provided as a space for interaction (such as discussion forums and wikis when using technology-mediated collaboration). In order for effective collaboration to occur, given that learners are strangers with little or no previous collaboration experience and with different cultures and personal experiences, it is important to provide a shared social context for learners to socialize, learn, and construct knowledge (Gao, Baylor, & Shen, 2005). To achieve coordinated collaboration, learners should be aware of three kinds of awareness: social awareness (who is around?), action awareness (what's going on?), and activity awareness (how are things going?). A shared context can be provided by a range of support features in the learning environment such as multiple information channels and tools to support coordinated collaboration in task-oriented projects; support for social, action and activity awareness; representations of objects in the environment; and communication scaffolds. Artifacts representing objects in the environment can be used to facilitate the building of a common ground, which is a critical process of knowledge construction (Ostwald, 1996). Communication scaffolds are used to structure discussions, elicit relevant information from lecturers, and enable learners to find different perspectives on similar cases (Lin, 2001).

Although groups can be used to pool ideas and experience of their members for better collective outcomes, poor performance may result because of a lack of positive group dynamics such as: lack of focus, poor communications, dominant personalities, social loafing, and "group think". The Delphi method (Linstone, Turoff, & Helmer, 2002) is a structured communication technique that solves the usual problems of group dynamics. It is a form of survey that can involve multiple iterations, where the process involves the structuring of asynchronous communication among a group of individuals looking to solve a problem or discover an answer to a question. It must be stressed that Delphi is a communication structure looking to examine a problem and open it for discussion, not a process for negotiation (Adler & Ziglio, 1995).

The main characteristics of the Delphi method are the structuring of information flow, regular feedback (through iteration), and anonymity of the participants. The process simply involves a series of iterations where a topic under discussion is circulated among participants (often experts in the area), who comment on it and, with each iteration, modify their opinion(s) when reviewing comments made. A moderator receives all the responses from participants at the end of each iteration. The responses are examined, packaged, and resent to participants for subsequent iterations. At some point (maybe when an agreement is reached) the iterations cease and a report is generated from the results.

A structured communication technique such as Delphi can be used to improve social interaction that, in turn, can result in higher-order thinking skills. This structured communication technique provides the basis to enhance learning outcomes, that can be categorised using Bloom's taxonomy. Bloom's taxonomy of educational objectives (Krathwohl, 2002) is a well-known framework for classifying what students should learn as a result of instruction. It outlines a range of thinking skills, beginning with lower-order thinking skills that form the foundation of the hierarchy that culminates in higher-order thinking skills. Bloom's (revised) taxonomy is specified as shown in Figure 1.

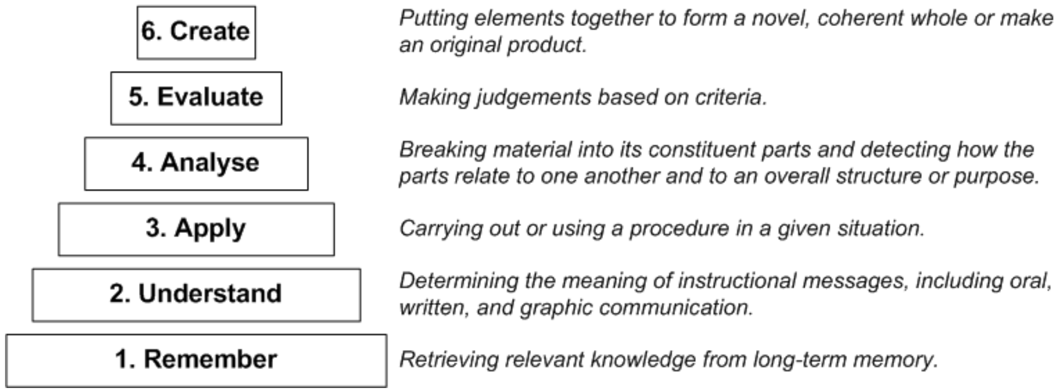

Figure 1: Bloom's (revised) taxonomy of educational objectives (based on (Krathwohl, 2002))

Technologies to Support Collaborative Learning

Computer-supported collaborative learning (CSCL) is related to supporting social learning with computers (Stahl, Koschmann, & Suthers, 2006) and can be divided into two aspects: collaborative learning and computer-support.

As the name suggests, the computer-support aspect of CSCL is the use of computers to support and facilitate collaborative learning and this has focused mainly on computers (and their networks, i.e., the Internet) in the past. However, with advances in technology, it should perhaps be widened to include other technologies. Although there is a body of work that investigates mobile CSCL (Cortez at al., 2004; Zurita & Nussbaum, 2004a, 2004b; Zurita, Nussbaum, & Salinas, 2005), it is based on personal digital assistants (PDA), e.g., Pocket PCs; devices that are no longer common. Furthermore, much of the research is related to primary education.

Prime candidates for consideration for mobile CSCL are smart mobile devices, in particular smartphones, which are more commonly available. Although there has been current research related to these devices and software applications (known as apps) that can run on these devices, they tend to have been piecemeal research and have not been clearly related to CSCL.

Mobile Learning Applications

Mobile learning applications are quickly gaining momentum. Since there is a large and diverse variety of them available, we categorise them to facilitate the ensuing discussion. We discuss mobile learning applications that promote higher-order thinking reported in the current literature, after which we position our study.

Categories of mobile learning applications

A categorisation of mobile learning applications based on learning theories is presented in Table 1. These categories are not mutually exclusive as an educational game can be categorised as both situated learning (if it occurs in an authentic context) and collaborative learning (if social interaction is used to construct knowledge).

Table 1: Categorisation of mobile learning applications
(adapted from (Naismith, Lonsdale, Vavoula, & Sharples, 2004))

Learning Theory and Key Theorists	Descriptions	Activities
Behaviorist learning (Pavlov, 1927; Pavlov & Anrep, 2003; Skinner, 1968)	Activities promoting learning as a change in learners' observable actions.	• Drill and feedback • Classroom response systems (clickers)
Constructivist learning (Bruner, 1966; Papert, 1980; Piaget, 1929)	Activities in which learners actively construct new ideas or concepts based on both their previous and current knowledge.	• Participatory simulations
Situated learning (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991)	Activities promoting learning within an authentic context and culture.	• Problem and case-based learning • Context awareness
Collaborative learning (Vygotsky, 1978)	Activities promoting learning through social interaction.	• Mobile computer-support collaborative learning (mCSCL)
Informal and lifelong learning (Eraut, 2000)	Activities supporting learning outside a dedicated learning environment and formal curriculum.	• Supporting intentional and accidental learning episodes
Learning and teaching support (No key theorists)	Activities assisting the coordination of learners and resources for learning activities.	• Personal organization • Support for administrative duties (e.g., attendance)

Of the learning theories presented in Table 1, our main interest is collaborative learning as it has an element of social interaction and constructivism, which promote higher-order thinking skills.

Mobile learning applications to promote higher-order thinking skills

There is a range of mobile collaborative learning applications available to promote higher-order thinking skills. These include discussion boards (Mac Callum, 2008), blogs (Huang, Jeng, & Huang, 2009), and outdoor educational scenarios (Vasiliou & Economides, 2007) and games (Barma & Daniel, 2011; Daniel, 2009). Discussion boards provide a medium through which learners can collaborate with each other and construct knowledge online. Blogs allow learners to develop and publish a piece of writing, which other learners can then comment upon. One way to achieve higher-order thinking is to provide learners with a complex problem, such as a case study, to solve, and use discussion boards and blogs as shared online collaborative spaces for interaction. Furthermore, allowing multiple channel access to these interactions (Peter, Vantroys, & Leprêtre, 2008), e.g., access through desktops, laptops, smartphones, enhances the environment for learners as they can interact with each other under different circumstances (e.g., on the move with a smartphone). In outdoor educational scenarios, learners are engaged in situated learning, and depending on the activity, also collaborative learning. Some example scenarios include learners visiting an archeological site and using mobile devices to transmit appropriate learner materials to each other, or learners participating in an orientation game in teams (Vasiliou & Economides, 2007).

Although these collaborative learning approaches have proven to promote higher-order thinking skills, they are mostly practical to be used outside of face-to-face classes to supplement in-class learning. That is, these applications cannot be actually used in the time-limited face-to-face lecture environment.

In contrast, clickers have been successfully used in the lecture environment as they are quick to set up and easy to use. Their inherent benefit is that they better engage learners and encourage learners who do not usually contribute in class discussions to participate (Beekes, 2006).

Clicker systems have evolved over time. Prior to the proliferation of smart mobile devices, in particular, smartphones, they consisted of "clickers", small physical transmitters, that transmit student answers to a centralised system (i.e., another piece of hardware), which receives and aggregates the responses. The clickers were either connected by wiring, or in more modern times, through infrared (IR) or radio frequency (RF) signals (Caldwell, 2007).

With the current uptake of smart mobile devices, researchers have begun to utilise mobile devices to replace clickers (Stav, Nielsen, Hansen-Nygård, & Thorseth, 2010). These newer systems have a number of advantages. Most students already have smart mobile devices, in particular, smartphones, so there is no cost for purchasing additional and specialised clickers. The older clickers that used IR or RF had a limited range. That is, it is necessary to be within a certain physical proximity to the receiver for one's response to be aggregated. This is not necessary with smart mobile device systems; as long as they are connected to a wireless network, their responses will be transmitted. In practical terms, this means that the new systems can be used to aggregate results synchronously (at the same time) for participants that are geographically dispersed. For example, the system can be used in a virtual meeting scenario in which participants are in different parts of the world. It is also possible to gather responses asynchronously (over time). So, an educator may pose a question in a distance education setting and analyse the aggregated responses a while later.

Even though clicker systems have evolved based on advancements in technology, simply using the clickers will not necessarily lead to higher-order thinking. If the clickers are used in a simple question-answer-feedback sequence, for which they are intended, then learners are engaging in the stimulus-response-feedback sequence of behaviorist learning (Naismith, et al., 2004). In off-the-shelf clicker systems, whether the older physical devices or the newer smartphone apps, there are no explicit mechanisms to elicit another round of responses and there is no social construction of knowledge imbued in any of the systems' processes.

It may be possible to use clickers to achieve higher-order thinking by posing carefully crafted questions. For example, it is possible to devise multiple-choice questions in which learners must calculate or logically deduce the answer (Dangel & Wang, 2008); however, there is no inherent social construction of knowledge. Learners individually determine their responses and, unless the instructor engages the learners in a process to discuss their individual responses together, knowledge is not socially constructed. Thus, the clicker system is simply a stimulus for discussion and interaction (Beekes, 2006); however, the instructor must enable and facilitate the ensuing discussion as the clicker system does not inherently support that.

Given the limited social interaction support in clicker systems for constructing knowledge, and the time consuming nature of truly collaborative learning systems, we propose *myVote*, a hybrid system between clickers and collaborative learning systems, for use in lecture-like settings. The *myVote* system will provide more explicit support for social interaction and use a Delphi-like process to facilitate the social construction of knowledge.

Collaborative System: *myVote*

We present an overview of *myVote* before we discuss the various parts of the system in detail.

Overview

The *myVote* system is designed to support social interaction in order to promote higher-order thinking skills. In this paper, we present its use in an educational setting; however, it is flexible enough to be adapted to other settings. Specifically, we use a lecture environment as a concrete example but it can easily be applied to a tutorial.

An overview of the environment in which the system will operate is depicted as a rich picture in Figure 2.

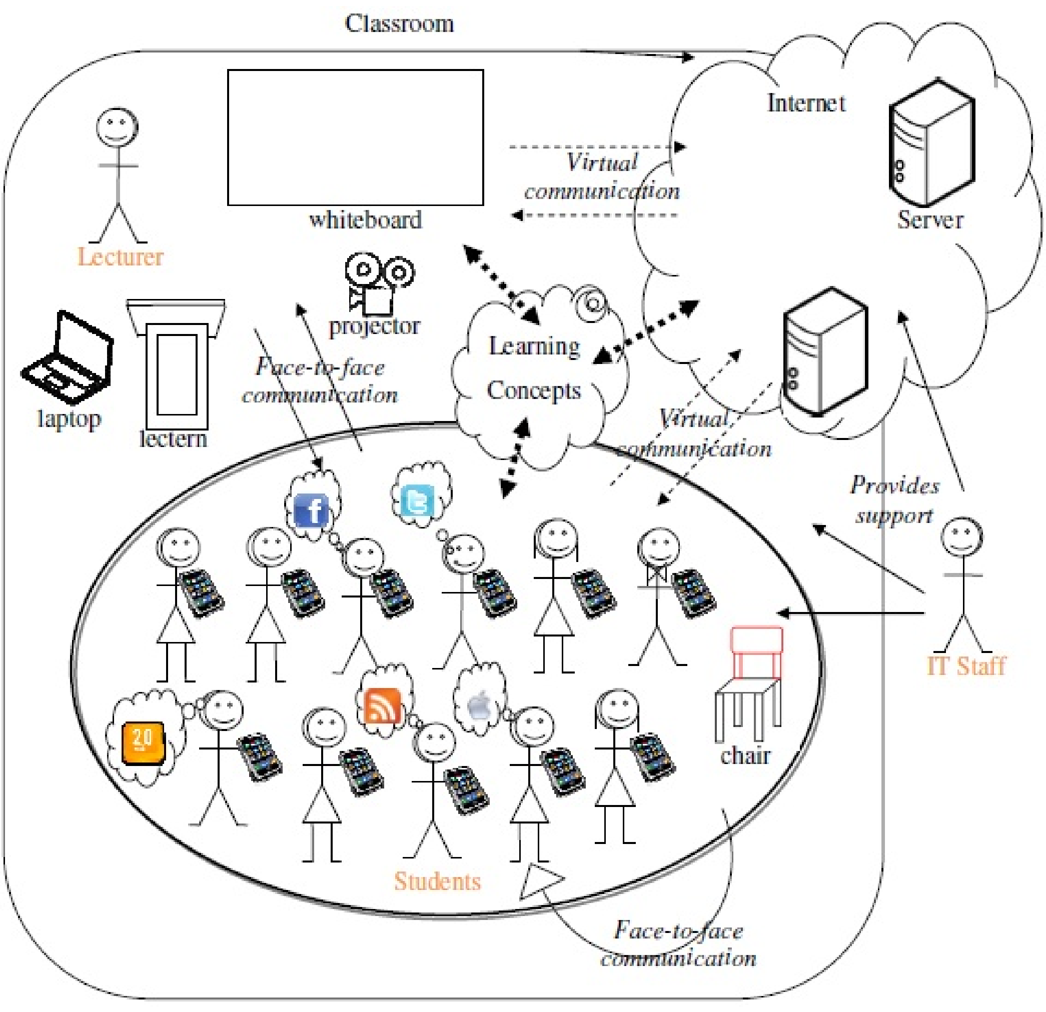

Figure 2: Rich picture of *myVote* collaboration system

As can be seen, there are some key differences compared to the traditional face-to-face lecture environment. The most obvious are the additional technologies in use, which are over and above the traditional laptop, projector, and whiteboard. The new technologies in use include the mobile devices (used by students), the mobile app (running on the mobile devices), and the servers.

An important distinction is that, although the collaboration system can be used in an asynchronous mode (as with many traditional CSCL systems), there is limited back and forth interaction through the system. However, the primary intention of the system is for its use in a blended face-to-face real-time computer-supported collaborative learning environment. In such a situation, it can be particularly effective as an inclusive system that shy students or those not willing to participate openly (e.g., in a show of hands) can use to contribute to the social interaction occurring in the face-to-face environment and be better engaged.

Another difference between a traditional lecture setting and the *myVote* scenario is related to how the technology is used. Students are using their own smartphone; *myVote* is implemented natively as both an iOS and Android app, and students are also able to access an additional web-based version. That is, students access the system simply by loading these apps on their smartphones, just as they do with all their other smartphone applications. Thus, the same up-to-date technology students currently have is used in the same way they typically use it.

A further difference is also related to technology. Audience feedback systems typically only allow for multiple-choice questions and answers. This limits higher-order thinking as people are typically better able to select answers from a given list rather than actually developing one on their own (MacCrimmon & Wagner, 1994). In contrast, *myVote* allows users, students in this case, to enter free text as responses. A Delphi-like method is used, as opposed to the standard voting process, to promote higher-order thinking skills.

Users

The users in the system are the academics and the students. There can be significant differences in these users' attitudes towards technology and education. In general, most academics are from an older generation known as the "baby boomers", born between 1943 and 1960 (Mangold, 2007). Although not averse to technology, baby boomers consider it to be something that is nice to have but not essential (Mangold, 2007). Other academics, particularly those in technology, engineering, and some science-related disciplines (e.g., information technology, software engineering, and computer science), may be more open and willing towards technology due to their technological interests.

The current generation of students is named "Generation Y", "Digital Natives", "The Net Generation", or "Millennials" (Mangold, 2007; Oblinger & Oblinger, 2005). All these terms typically describe students born between 1980 and 2000; a generation that has lived with technology from their birth. The implications of this are that these students, who are the majority in most universities, are very technologically literate and view technology as a necessity (Mangold, 2007) rather than a luxury. Key characteristics of these students are that they are constructivist learners (McNeely, 2005; Prensky, 2006) and enjoy social interaction (McNeely, 2005).

From these two different groups' view on technology, it is likely that although students may welcome new technologies simply because of their affinity with technology and the novelty of the technologies, academics will need to be better convinced of the technological gains in order for them to accept and put them into practice. In such cases, practicality, ease of use, and a gradual learning curve are important.

The roles these two types of users play in the system are also different. By default, students are obviously in the role of a learner, and the lecturer, as is the case with collaborative learning approaches, is in the role of a facilitator. That is, the lecturer does not dispense knowledge to students; instead he/she facilitates their learning. However, these roles can change as students can also at times act in a facilitation role, e.g., when they are called upon to justify their answers.

In the case of *myVote*, careful consideration is given to these two types of users. The system is practical and easy to use for both. The lecturer simply needs to log into the system and follow the online steps while students download the mobile app and follow the steps within the app. These are common tasks that these users typically perform on a daily basis in educational environments.

Processes

In a lecture-like environment, where there can be a large audience, it can be difficult to engage students as it impractical to actively interact with each student during the short time frame available. Similarly, encouraging social interaction is also difficult, as it needs to be effective and efficient within the duration of the lecture. Traditional approaches, such as a “show of hands” to answer a question, are not particularly effective, as many students do not participate in such activities. The *myVote* system can be used to address these issues; however, the technological aspects of *myVote* provide only the mechanism through which this can be achieved. Thus, a process that guides how *myVote* is used is necessary. As the Delphi method can be used to structure communications to achieve positive group dynamics, it is appropriate for the *myVote* process to be modelled upon it.

The first desirable characteristic of the Delphi method is that it is a structured approach to communication. In a lecture environment, where there can be a large audience, this is important as it allows the lecturer to control communication efficiently and effectively within the duration of the lecture. A second characteristic is regular feedback through multiple iterations of the survey. This plays a crucial part in a learning environment, as it is feedback that ultimately allows students to learn. The third characteristic, anonymity, is a more practical one. Typically, in large learning audiences, there are quite a number of students who are reluctant to actively participate due to shyness or lack of confidence. This can greatly hinder their learning in such an environment and may fail to engage them appropriately. However, the *myVote* system provides these students the ability to participate non-verbally and anonymously. In the design of the *myVote* process, it was ensured that these three characteristics, as well as the general iterative process of the Delphi method, were present.

The *myVote* process begins when the lecturer enters a question into the *myVote* system through the web client. The *myVote* system then sends a push notification to the mobile apps of registered users, i.e., students enrolled in the class. Upon receiving the push notification, students select the most appropriate answer and send their responses back to the *myVote* server. This part of the *myVote* process is similar to the Delphi process in which participants comment on questions or a topic of discussion. In the case of *myVote*, students’ comments are in the form of an answer to a multiple-choice question. Although this is more restrictive, it is an important aspect of the *myVote* process.

The Delphi and *myVote* processes operate under different circumstances and environments. The Delphi process is typically used in an asynchronous manner and not in a face-to-face environment. Thus, there is no strong sense of time restriction. However, the *myVote* process typically operates in a lecture-like environment in which there is a sense of immediacy and, in that environment, synchronous communication is desirable. One way to alleviate the restriction of a limited response in a limited time frame is to take advantage of the face-to-face environment in which the *myVote* system is used; face-to-face verbal discussions. This occurs next.

As students submit their answers to the lecturer’s question, the server aggregates the results and the lecturer can display a histogram of results to the entire class. Students are then able to see the responses of the entire class at once and can compare their answers with those of the entire class. A quick comparison of their own results against that of the entire class provides individual students with immediate feedback about their response. This is a simple, but yet powerful mechanism for feedback. This quick feedback is similar to the traditional “show of hands” activity; however, the difference is that, through *myVote*, anonymity is preserved. This is an important and crucial difference as more students are likely to respond because, through anonymity, there is no risk of others knowing that one has answered incorrectly. Thus, the overall effect is that there is increased student participation. A side effect is that this can build confidence for students whose answers form the majority.

By comparing their responses to that of the entire class, students get quick indicative feedback about the correctness of their answers. However, there is a possibility that the majority of the class could have selected an incorrect answer (e.g., due to a common misconception or mistake). Thus, to assert correctness, consolidate the responses, and provide further feedback, some sort of lecturer intervention is required at this point. This is equivalent to the moderator examining and packaging responses in the Delphi process. There are a number of actions that the lecturer can undertake at this point. For example, the lecturer can discuss or elaborate upon the responses. Depending on the importance of the topic and the percentage of correct answers, this can be done at length and thoroughly, quickly discussed, or postponed for later discussion which can be either face-to-face or through a discussion board. As it more likely that more students will have answered the question through the *myVote* system compared to a show of hands, the lecturer has a better view of students' understanding and can more confidently decide how in-depth the discussion should be. Alternatively, the lecturer can ask students to volunteer justifications for their answers. This provides for better engagement and although it is does break anonymity, it is the students' own choice as they volunteer to explain their answers.

Note that in the aforementioned discussion, the lecturer should not reveal the correct answer to students. Instead, in the role of a facilitator, the lecturer should guide students towards understanding the material by discussing the various answers, examining students' thought processes in answering the question, recalling or presenting new material relevant to the question, etc.

After discussing the responses, the lecturer re-sends a second round of the same question through the *myVote* system, just as the moderator packages responses and re-sends them to participants for a subsequent iteration in the Delphi method. As with the Delphi method, this subsequent iteration allows students to review their responses and change them (if they so desire) in light of the feedback they have just received. The new histogram is then presented to the entire class, and the iterative aspect of the process continues.

The iteration can be repeated multiple times, until the lecturer decides to terminate it. This may occur when the great majority of students have selected the correct answer (i.e., the lecturer is confident the majority of students have understood the topic of discussion), or this topic is proving too difficult a concept to discuss in this environment and the lecturer will discuss it in-depth later on.

An alternative version of this process is to allow students to respond by sending free-text answers (as opposed to selecting an option provided by the lecturer) and to arrive to a consensus by removing inappropriate answers. In case there is a multitude of free-text responses added from students with certain elements of similarity between them, the system can reduce these using text mining techniques in real-time. Incoming responses are classified on the server using appropriate techniques, such as nonnegative matrix factorisation (Janecek & Gansterer, 2010). This grouping of similar responses assists the lecturer to interpret the histogram of results.

The *myVote* collaborative learning system can be used in a number of different ways in an educational setting to better engage students, promote social interaction, and to lead to higher-order thinking.

User Experience

The user experience, which includes the user interface and usability, is another important aspect of the system to be considered. When developing the system, it must conform to the interface design and interaction style norms set out in the majority of applications developed for their respective operating environment, e.g., WWW, iOS, and Android.

The *myVote* system provides some common components, terminology, and icons across the various devices but ultimately the operating system on the mobile device will dictate interface design and interaction styles. This is done to match the mental models that the users have developed in using their mobile devices. These guidelines are commonly found in many usability guidelines, such as Nielsen (1994). Usability heuristics, such as “recognition rather than recall” and “match between system and real world”, highlight the importance of using the appropriate terminology, following the expected conventions and minimising the users’ memory load by matching the user mental model.

These are important usability guidelines that the *myVote* system needs to conform to. A mockup of the iOS version of the mobile app running on an iPhone is shown in Figure 3. Note that for the question presented (Figure 3a), four options (A-D) are available, and there is also the possibility to add another option (as free text). In the results screen (Figure 3b), the four options are shown along with any other user-submitted options (in this case, the new answer is marked as option “E”).

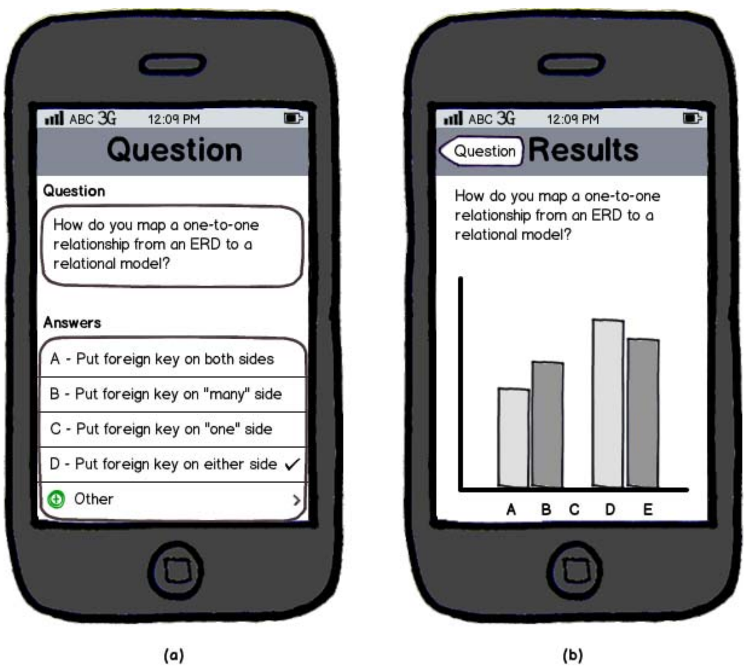

Figure 3 Sample *myVote* app mockup screenshots

Applications of *myVote*

After having explained the design of the *myVote* system, we now describe three usage scenarios in IT education to demonstrate its usefulness in stimulating different cognitive levels based on Bloom’s taxonomy (Krathwohl, 2002). The first scenario describes a common usage of *myVote*: reinforcing or checking students’ understanding in an ad hoc fashion during a lecture. The second scenario shows how *myVote* can be used to elicit knowledge, while the third scenario demonstrates how to use *myVote* to promote critical thinking.

Scenario 1: Reinforcement through Consensus Building

A lecturer is teaching the mapping of Entity Relationship Diagrams (ERD) to relational models in a 12-week long undergraduate introductory database course. After describing the ERD, the relational model, and the mapping between the two, the lecturer wishes to reinforce the concepts. He/she can do so using *myVote* and all students can actively participate by selecting what they believe to be the most correct answer from a given set of answers using their mobile device.

The lecturer uses the *myVote* web client to push the following question to the enrolled students: *"How do you map a one-to-one relationship from an ERD to a relational model?"* and provides the following set of answers for the students to select from:

A. Put a foreign key on both sides
B. Put a foreign key on the "many" side
C. Put a foreign key on the "one" side
D. Put a foreign key on either side (but only one)

Once the students receive notification of a new question on the *myVote* mobile app running on their own smartphones, they submit what they believe to be the correct answer. Using the *myVote* web client, the lecturer once again accesses the system to display a histogram of all answers to the students. Students can also see the histogram on their smartphones in the *myVote* mobile app. In this case, the histogram shows that most students have selected option D. Thus, after submitting their vote, students get immediate feedback about their response. Although, this feedback is indicative, it is necessary for the lecturer to further elaborate upon it in a verbal discussion. As the great majority of students have selected the correct answer, option D, the lecturer sees little value in discussing the question at length. Thus, the lecturer asserts that this is correct and moves on, knowing that most students understand the concepts being discussed.

The lecturer continues to check the students' understanding by sending another question through *myVote*, *"How do you map the most common relationship, one-to-many, from an ERD to a relational model?"* and supplies the same set of alternative answers as in the previous question.

Once again, the students submit their answers using the mobile app. This time, the histogram shows that most students selected option B (the correct answer); however, a significant number of students selected option C.

Although most students selected the correct option, the lecturer notices that a significant amount of students selected the same incorrect answer, C, and is concerned that there may be some common misunderstanding among the students. To further investigate the issue, the lecturer decides to spend some time discussing the question further.

The lecturer asks for a student who has selected option C to volunteer justification for his/her answer. The volunteer states that a foreign is needed on the "one" side of the one-to-many relationship, which is a common misconception. The lecturer then asks for a volunteer who has selected option B to provide some justification. The student states that a foreign key should be placed on the "many" side of the one-to-many relationship, but not on both sides or on the "one" side as those would be incorrect. The lecturer discusses the two responses and asks students to recall the three rules related to mapping relationships between ERDs and relational models (one which states that for a one-to-many relationship a foreign should be placed the "many" side of the relationship).

After the discussion, in which the correct answer was not revealed, the lecturer re-sends the question through *myVote* (i.e., the second iteration of the question) and students re-submit their updated answers based on the discussion. The histogram shows that all students have selected option B. Confident that the students understand the material covered, the lecturer moves on with the lecture.

Scenario 2: Eliciting Knowledge

A lecturer is teaching the mapping of ERDs to relational models as discussed in the previous scenario. Having already discussed two types of relationships with different cardinalities between entities (one-to-one and one-to-many), the lecturer discusses a third type of relationship, many-to-many, and sends the following question to the students through *myVote*: *"How do you map the many-to-many relationship from ERD to relational model?"* He/she supplies the students with the same set of answers as the question in the previous lecture.

After the students submit their answers through the *myVote* app, the histogram reveals that many students have selected option A, which is a common mistake. Additionally, one student has submitted an unlisted answer (i.e., one that he has made up), *"Create a new table and add the primary key from both tables as a concatenated primary key in it"*. The lecturer facilitates a verbal discussion to explain the problem with option A and invites the student who submitted the new answer to elaborate on it. If there were multiple new answers, the text-mining capabilities incorporated in the system would consolidate similar answers together. However, as there is only one new answer in this case, the system adds it to the original list of alternative answers and the lecturer sends the question again to initiate the second iteration and the students update their answers. The histogram now shows that most students have selected option E, the correct answer, which was previously unlisted. The lecturer then elaborates why this is the correct answer.

Confident that most students understand the material under discussion, the lecturer moves on to discuss the actual implementation of such a relationship. As the students determined in the last question, this requires the creation of a new associative table. To highlight one issue that occurs with the addition of the new table, the lecturer discusses the naming of the associative table and points out that there is no obvious name readily available. As a concrete example, he draws an ERD on the whiteboard. The ERD shows a set of tables (without attributes) to store information about songs in a music collection (refer to Figure 4).

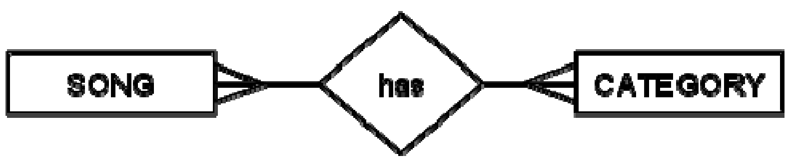

Figure 4 Sample many-to-many relationship

The lecturer states that the associative table in the example should have no attributes other than the concatenated primary key composed of the primary keys of the song and category tables in the diagram. The lecturer pushes a question to the students through *myVote*, *"What should the associative table be named?"* and does not provide any list of possible answers.

Some students independently create names for the table and submit them through the *myVote* app while other students do not submit any responses. The text mining functionality of the system aggregates the responses into common categories. The lecturer pushes the question again through *myVote*, however, this time he/she provides only the four most common categories as possible answers:

A. SONGCAT
B. SONGCATEGORY
C. CLASSIFICATION
D. HAS

Students submit their responses and the histogram shows that significant portions of the students have selected either option A or C. The lecturer discusses that there is no clear approach to naming such tables and that some textbooks recommend a subset of letters from the name of each entity involved in the relationship to construct the name of the associative entity. However, it is sometimes possible to deduce a logical name, such as "classification", in this case.

Scenario 3: Promoting Critical Thinking

After having understood various key concepts related to data modelling, students next undertake an assessment task. The assessment task requires the implementation of a many-to-many relationship, which was discussed in a previous lecture (described in a previous scenario). However, students are still having some difficulty with the implementation.

To initiate the discussion, the lecturer re-visits the previous lecture by posing the same question as he did previously (refer to the previous scenario) and provides five alternatives. The question is re-issued through *myVote* as a new iteration of the question. Students view their previous answers (from the last time they answered the question) and determine whether they want to submit a different answer or not. The histogram of responses show that over half of the students have selected option E, *"Create a new table and add the primary key from both tables as a concatenated primary key in it"*, and an additional answer was submitted by one student as: *"Create a new table and add to it a new surrogate primary key and two foreign keys from each side of the relationship"*. This prompts the lecturer to initiate another iteration of voting with only these two options as possible answers.

The histogram now shows that although over half the students have selected the first option, a significant number of students have selected the new option. The lecturer explains that both answers are correct as they both provide a valid mapping of the relationship. He/she then explains the advantages and disadvantages of both options from an implementation and data modelling perspective.

Discussion

The *myVote* system is designed to support collaborative learning. In this paper, we explain how it can be used for lecture-like settings in order to better engage students, to encourage social interaction, and to support collaborative learning. In the design of the system, the users, processes, and user experience were taken into consideration. The *myVote* system process is loosely based on the Delphi method, and the technological implementation provides the required functionalities to support the iterative and interactive construction of knowledge. Although the system is flexible enough to be adapted to a number of different environments, this paper is restricted to its use in a lecture-like educational environment. We next discuss the various aspects of *myVote* in relation to such an environment.

Advantages of myVote

The particular strengths of the *myVote* system are that it is based on collaborative learning, is practical (easy to use), and is congruent with modern students' use of technology. These strengths should encourage adoption and acceptance with both academics and student cohorts. The mobile app, in particular, is something that modern students use on a daily basis it is likely to better engage students and promote adoption.

The system process, loosely inspired by the Delphi method, provides a mechanism that will allow large audience communication over a short period of time in a blended learning environment. The process includes important characteristics of the Delphi method, such as anonymity, iteration, feedback, and reflection.

Anonymity causes the process to lead to better inclusiveness than the traditional "show of hands" approach, as shy students or those not willing to communicate openly are more likely to submit answers through the *myVote* system rather than raise their hands.

The other three Delphi characteristics (iteration, feedback, and reflection) allow students to get feedback on their answers and alter them if necessary; a crucial part of the learning process. Students receive feedback in two different instances. The first is when they view the histogram of results. This provides them with an indicative and relative feedback about their answer compared to that of other students. The second instance is when the lecturer intervenes and provides his/her perspective about the histogram. The lecturer also receives feedback about the entire class. This is important as it will allow him/her to determine how much more time needs to be spent on this particular question or topic.

As the *myVote* system is based on collaborative learning, it inherits benefits of being student-centered and of promoting social and active learning. Using a student-centered approach allows students to take charge of their own learning and allows the lecturer to take on the role of a facilitator to guide the students. Active and social learning are also beneficial as they allow for higher order thinking.

Stimulating Different Cognitive Levels

Three different scenarios were used to illustrate the potential usage of the system. The scenarios illustrate how the system can be used within a single lecture or throughout a semester-long course. The scenarios also demonstrate the flexibility of the system and how it can be used to stimulate different levels of cognition by framing questions based on different categories of Bloom's (revised) taxonomy (Krathwohl, 2002). The level of thinking required in the three scenarios ranges from lower-order thinking to higher-order thinking.

The first scenario tests learners' comprehension by simply allowing them to select from a list of possible answers. This is a typical multiple-choice question used in many audience feedback systems and is related to second category, "Understand", of Bloom's revised taxonomy as learners must understand the question and select the correct answer from a list of alternatives.

The second scenario requires a higher level of thinking, as learners have to suggest (i.e., create) an answer. The scenario demonstrates the possibility for lecturers to ask questions without providing answers from which students make a selection or to provide a list of options from which the correct answer is missing. This enables students to apply knowledge obtained from the traditional lecture presentation. It is categorised into the third category of Bloom's revised taxonomy, "Apply", as the learners must apply the concepts learnt to deduce or formulate the correct answer.

The third scenario does not have a correct answer as such. Instead, learners are required to discuss possible alternatives, which requires critical analysis skills (higher order thinking). This is related to the fifth category, "Evaluate", in which learners have to critique various approaches when there is no definitive correct solution. Additionally, the scenario demonstrates the longitudinal use of *myVote* throughout a semester of study. A concept discussed at an earlier point in a learning and teaching cycle can be reviewed, certain aspects can be re-covered, and new knowledge (or perspectives) can be generated or explored by the *myVote* system. The trigger for the re-visitation of the material is due to the experiential learning in the assessment work and the exploration of new concepts using *myVote* enhances the learning outcomes for the student body as a whole through active participation in the discussion.

Communication Modes

Use of the *myVote* system in a lecture-like environment provides an additional channel of communication. We have developed a process loosely inspired by the Delphi method to manage this additional communication channel. Thus, the *myVote* process inherits a number of benefits from the Delphi process. These benefits are mainly for the practical usage of the system. That is, in a lecture-like environment with a large audience, it is useful to have a structured approach to communication. Regular feedback through multiple iterations of the survey informs students' learning, and anonymity encourages shy students (especially those who have low verbal communication skills) to contribute to the collaborative learning process when they may not do so in typical lecture settings.

In lecture-like settings, there is a strong sense of immediacy, and synchronous communication is typically used. However, the *myVote* system and the Delphi method, on which it is based, use asynchronous communication. To address this, the *myVote* process uses asynchronous communication over a short time period. That is, students send their responses asynchronously and after a few minutes, the lecturer discusses the results. The discussion of the results is done verbally (i.e., synchronously) to take advantage of the face-to-face aspect of the blended learning environment. This approach is practical as the asynchronous part effectively aggregates student answers and the synchronous portion allows efficient discussion.

Although we have discussed this mixed communication mode in the three scenarios, it is possible to use the *myVote* system in a purely asynchronous mode. For example, the scenarios can easily adapted to occur in a distance learning situation in which students submit answers through *myVote* and discussions occur through discussion boards, emails, or online chat systems. Alternatively, the lecturer can pose a question outside of regular class time through the *myVote* system, and students can investigate the question, identify answers, and respond using the system. After submitting their initial response, students can view other students' responses and review their answers if necessary. This approach, which is not as time restrictive as in a lecture-like setting, is likely to promote the benefits of asynchronous learning (Mayadas, 1997), such as allowing learners more time to investigate, consult, and reflect before submitting an answer.

Limitations

A potential limitation of *myVote* is that it may not be appropriate for technical IT materials, such as programming code or SQL commands as there may little or no social construction of knowledge. In such cases, the learning maybe restricted to lower-order thinking, such as "Understand". However, if questions about these materials can be re-formulated into pseudocode, social construction of knowledge can occur.

Another potential limitation is that communication through the system is strongly structured (i.e., in the form of question and short answer), which can be limiting; however, flexibility is added through discussions. In the scenarios described in this paper, these discussions occur verbally in a face-to-face environment; however, they can also occur through other communication channels such as discussion boards, emails, and online chats. Thus, discussions are an important part of the system process as they promote social interaction, and, in instances in which the lecturer does not allow discussions to occur, the system will be of limited value in terms of knowledge construction.

Non-educational use of myVote

Although we describe the application of *myVote* in an educational setting, namely in a lecture situation to better engage students and promote social interaction, the system is flexible enough to be utilised in other settings, such as face-to-face and virtual meetings, product and/or service feedback, and opinion polls, for interactively constructing better collective knowledge/solutions.

Future Work

As our contributions in this work are conceptual in nature, we only discuss the merits and issues of the system on a theoretical basis. However, once the system is developed, it must be trialled and evaluated in multiple courses and scenarios. It is not easy to objectively measure the learning outcomes, as it is difficult to set up controlled environments for evaluating experiments in these educational settings since there are many variables involved and many of them cannot be controlled.

As we cannot reliably isolate the phenomenon to be measured, in such an evaluation, we must rely on self-reported measures, which may not be accurate. To address the inaccuracies, a triangulation approach should be used, namely a survey questionnaire, focus groups, and analysis of system data.

The survey questionnaire will be used to gain broad insights about both the learning outcomes achieved and the uptake of the system in the educational environment. The survey participants will consist of both students and academics, and the survey will enquire about the usability and other practical aspects of the system. To further examine those insights into the usage and learning outcomes, selected candidates will be asked to participate in focus groups to engage in deeper discussions. Data submitted to the system, i.e., answers submitted by students, can be used to cross-examine self-reported outcomes in the survey and focus groups. In particular, the quality of the data, e.g., correctness of answers over time, can roughly be used to gauge learning outcomes. The frequency and amount of submissions (i.e., answers) can be used to gauge the usage of the system.

Once the system has been developed, it will be possible to not only trial it in lecture-like environments as discussed in this paper, but also use it to explore how other collaborative learning environments can benefit from the system. For example, the use of the *myVote* system can be trialled in student group work situations, i.e., project-based learning. Students collaborating in groups often encounter disagreements and can use the *myVote* system to reach consensus. Similarly to lecture-like environments, in face-to-face group discussions some students do not like to voice their opinions openly (Cheong, Tandon, & Cheong, 2010) and *myVote* can be used to address that issue.

On a grander scale, it may be possible to use the *myVote* system to develop a new teaching approach that may be more appropriate for modern students. For example, given that students carry out prescribed reading prior to attending classes, it is possible to envisage a teaching approach in which the lecturer uses a series of questions in the lecture to cover required material and pose questions that would lead to appropriate discussions. This student-centered teaching approach can be further augmented with more student-centered elements. For example, while carrying out the prescribed reading prior to the lecture, students are able to send questions through the *myVote* system. The questions can be sent to either the entire class and the lecturer, or just a small group of friends/collaborators. If the questions are sent to the lecturer, he/she could pick out the most salient ones and include them in the actual lecture. Of course, it would not be appropriate to teach all courses in such a manner and further work is required to determine which types of courses or topic materials are appropriate. Additionally, guidelines and best practices would be extremely beneficial.

Conclusion

We have presented a conceptual system to address the passive engagement of students, and to promote higher-order thinking skills, in lectures. The system, named *myVote*, is a mobile-app-based collaborative system developed using collaborative learning theories. We also describe a process for using the system in order to address various levels of thinking.

To demonstrate the flexibility of the system, we describe its usage in three separate scenarios to address different levels of thinking. In the first scenario, the system is used to engage students in lower-order thinking ("Understand", the second category of Bloom's revised taxonomy), by providing students with a list of answers from which they need to select the correct one. Although lower-order thinking is not as desirable as higher-order thinking, it is important as it develops a foundation to ultimately achieve higher-order thinking skills. In the second scenario, we illustrate how the system can be used to achieve the third category, "Apply" in Bloom's taxonomy by allowing learners to submit their own answers instead of selecting from a predetermined list of answers provided by the lecturer. The third scenario demonstrates how the fifth category of Bloom's taxonomy ("Evaluate") can be achieved using *myVote*. This involves asking the students a question and not providing any potential answers. Additionally, as there may be multiple correct answers, students must critique various solutions in order for them to determine what they believe to be the best answer. The third scenario is also an example of longitudinal use of the system as the lecturer poses a previously asked question to students.

Our main contribution is the framework for using mobile apps and collaborative learning theories in a lecture environment to promote higher-order thinking skills in learners.

One potential limitation of the system is that it may not promote higher-order thinking for teaching some materials, such as technical IT materials (e.g., programming or SQL). Another potential limitation is that the discussion that occurs after the learners have submitted their answers is important, without which the system will have limited value. The first limitation can be addressed by re-formulating the questions into a less technical format (e.g., pseudocode). Regarding the second limitation, since discussion is required for promoting social construction of knowledge, the system should be used as intended to obtain its full benefits.

Future work involves the development and trial of the system and the development of a teaching approach in which the lecturer uses the system and engages students to discuss the required material throughout an entire lecture. In this approach, students could also send their own questions to the entire class or a small group of friends/collaborators.

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Biographies

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His general research interests lies in the areas of artificial intelligence, intelligent agents, evolutionary computing, software engineering, and modeling and simulation. He is interested in applying these to various domains, including education.

Dr Vince Bruno is a lecturer at RMIT University, College of Business, School of Business IT and Logistics. He holds a Bachelor of Applied Science (Computer Science), a Master of Computing (IT), and a Ph.D (Business Information Systems). His PhD thesis is titled "Improving Usability Outcomes in IS Projects: the Views of Usability Practitioners".

His research interests include usability methodologies and practice, IT education, databases technologies, application development and solving problem using IT.

Dr France Cheong is a senior lecturer in the School of Business IT and Logistics, RMIT University. He holds a Bachelor in Business (Computing), a Master of Computer Science, a Master of Education, and a Ph.D. (Computer Systems Engineering).

His research interests include the modelling and simulation of complex systems using a wide range of techniques such as: fuzzy systems, evolutionary computation, artificial immune systems, agent-based modeling and system dynamics. He has applied these techniques to engineering, business applications, and education.