A Layered Model For Extensible Mobile PRS -
Using Design Science Research Methodology To Improve The Use Of
Mobile Technology

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Abstract: Current personal response systems (PRS) commonly referred to as ‘clickers’ are not part of a common communications platform. PRS and other telecommunications devices owned by the students and in the classroom with them use mutually exclusive vertical tracks or message protocols. This paper provides a technical description of the problem and a solution that allows students to respond to learning activity sessions (e.g. a poll, vote or answer to a question) with a variety of devices (smart phones, wireless tablets, and netbooks) in an integrated, flexible manner using a transparent different delivery option (e.g. HTTP)

Introduction

In the recent past, one of the technology advances has been the use of personal response systems (PRS) in the class room. These are systems that allow students to respond to questions, or interact in some way during the class delivery, and have those responses or interactions collected in real time by the instructor. This was originally facilitated by specialized handsets, or response devices, a wireless receiver, and accompanying software for presenting results. Inevitably, people turned their attention to less proprietary devices, and looked at the ubiquitous mobile handset, as an alternative device.

Originally, the primary benefits for using mobile devices over proprietary devices were based on the limited functionality of the proprietary handsets. The earlier models of PRS were limited to simple yes/no functions, and later extended to a wider set of discrete responses that included selecting options like A, B, C, D etc. This generated a surge of interest in mobile PRS, which in turn identified its own set of advantages and disadvantages over proprietary systems. In a review of recent journal and conference papers none explore the idea that a mix of students’ devices commonly found with them in the classroom could be used as PRS. (Bachman, L. & Bachman, C. (2011), Sridhar, et al.,(2011) and Yengin, (2011))

This paper discusses the extension of the capabilities of mobile PRS, so that mobile PRS is still current for teaching today, and is positioned to continue to provide additional value to learning in the near future. The approach that this research takes is to propose and develop an extensible framework for messaging, primarily in the mobile PRS context and to propose how classroom teaching can be more closely aligned with new collaborative styles of learning that are nominally associated with new paradigms of learning being adopted and supported by the changes that Web 2.0 is making to the electronic learning experience.

This research also explores and validates the proposed research methodology, design science research methodology (DSR), which underpins this research (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). As a technologist with strengths in building and developing systems, it is important that both this body of work, and those of similar minded colleagues, is acknowledged. This contrasts to the more established research methodologies in other sciences, (Sekaran, 1992).

This paper is laid out in the following manner, first is a discussion of a theoretical Mobile PRS, followed by a detailed description of the proposed experimental model, this is then followed by a descriptions of its application, and lastly a discussion and conclusion.
DSR Mobile PRS - Theory

From the very outset of this research, there has been a conscious awareness of the overriding methodology selected (DSR) and of the different evaluation methodologies of observational, analytical, experimental, testing and descriptive (Hevner, March, Park, & Ram 2004). As the design of the artifacts created have evolved, there are shifts in applicability and relevance of the DSR guidelines and their detail, just as there have been changes in the final artifacts themselves.

The domain space for mobile technologies changes rapidly, often with irregular quantum leaps in functionality and capability. The leap from the basic mobile handset with SMS to PDA is significant, and the impact that the iPhone has had is iconic. Less public but no less significant, the advent and portability of the netbook means new platforms, transport, and delivery options are ever likely to be disruptive in the arena of m-learning.

This paper provides two artifacts; one is a model (i.e. layered model for extensible mobile PRS), and the other artifact is an instantiation, (i.e. a prototype) that demonstrates the validity of the proposed framework. We have reviewed previous literature and there have been architectural models that provide integration of a heterogeneous range of response devices (Colazzo, Molinari, Ronchetti, & Trifonova., 2003; Andronico, Carbonaro, Colazzo, Molinari, Ronchetti, & Trifonova, 2004; Colazzo and Molinari, 2004). The contribution of this research is differentiated by the following major dimensions; a) this proposes a layered model and not a modular component model, b) this model extends beyond the software architecture and connects the presentation layer and more significantly, connects the different learning styles, providing an insight on how these could be leverage for Web 2.0 learning.

This research is intended to be evaluated on the seven guidelines presented by Hevner et al. (2004) in relation to DSR in the domain of mobile PRS and m-learning.

<table>
<thead>
<tr>
<th>Guidelines</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design as an artifact</td>
<td>DSR must produce a viable artifact for mobile PRS.</td>
</tr>
<tr>
<td>Problem Relevance</td>
<td>Does it solve a specific problem in the area of mobile PRS or m-learning in general?</td>
</tr>
<tr>
<td>Design Evaluation</td>
<td>Has the layered model for mobile PRS been designed in a manner that can demonstrate the utility, quality and efficacy of the artifact with respect to the problem relevance?</td>
</tr>
<tr>
<td>Research Contribution</td>
<td>Is there a clear contribution that the artifact makes to the established knowledge base and domain of m-learning?</td>
</tr>
<tr>
<td>Research Rigor</td>
<td>Is the layered model for extensible mobile PRS derived from the extensive body of knowledge?</td>
</tr>
<tr>
<td>Design as a Search Process</td>
<td>How has the iterative process of the generate/test cycle impacted on the artifacts produced by this research?</td>
</tr>
</tbody>
</table>

Table 1: Guidelines for evaluating DSR

Layered model for mobile PRS

This section describes how to organize the domain space from the perspective of a layered model. Layered models have been used frequently in the science disciplines and help break down complexity, promote research and innovation, assist trouble shooting and fault finding, and facilitate teaching and learning as the complex domain is divided into small, typically modular areas of functionality. Typically layered models are interpreted from the bottom layer up, with each layer providing a set of services to the layer above.

Layered models have been used in e-learning before. As we have seen from the literature review, Suzuki and Keller (2007) proposed a model that could be used to help build an effective e-learning course. This was not a layered model in the sense that each layer provided a set of services to the layer above, rather it sets out the baseline level (layer 1) for good practice and aims of instructional design, and the layers below detract from the baseline, and layers above build on the foundation elements of layer 1.

We present a 6 layered model for mobile PRS. Layer 1 is the Platform layer and deals with the heterogeneous range of hand held response devices that might be available to learners. Layer 2 address the Transport layer, and deals with how a signal can be sent from the handsets (layer 1) to the layer above. Layer 3...
is the **Delivery** layer and deals with how the information from a signal should be formatted in a particular way that will have meaning to an application. Layer 4 is the **Application** layer which contains the logic, computation and analysis to support a range of learning activities. A subsection of layer 4 is the **Delivery-To-Application** middleware, and this is the major process that addresses the integration problem introduced in this chapter. Layer 5 is the **Presentation** layer and suggests that the instructor is able to choose from a number of visualization options to support the underlying learning activity. Layer 6 is the **Learning** layer, and shows how the m-learning environment exists to support a number of learning paradigms and how these can support the big ideas in education emerging from the use of Web 2.0 services.

![Layered Model for Extensible Mobile PRS](image)

**Platform Layer**
This layer is intended to support the heterogeneous range of input devices available with wireless technology. This includes mobile phones, PDAs, netbooks, laptops, iPhones, and proprietary clickers. The common technology that underpins these devices is that they are capable of transmitting a signal remotely and wirelessly. This layer emphasizes that accessibility into the m-learning environment should be seen as focusing on accommodating a mixed technology platform.

**Transport Layer**
Currently, the standard medium of choice for electronic devices to send signals without being tethered to the receiver is the electromagnetic spectrum. The approach is to modify the regular oscillation of self-propagating waves that occur naturally as a result of the phenomenon of electromagnetic radiation, under a set of rules or parameters, such that a specific modification represents one or more discrete values of information. While the electromagnetic spectrum is large, the following two factors have a significant impact on how it is used as a data communication medium: a) the relatively small proportion that is useful for the purposes of
wireless data communication, and b) the regulation of this limited resource into licensed and unlicensed bands.

Mobile telecommunication providers will tend to operate in the licensed bands, having acquired this resource from the government, while devices like remote controls, wireless LANs (802.11) will operate in unlicensed bands that allow anyone the use within specification constraints including interference with other providers in the space, and considerations of any effects of public harm. Within the context of this research, mobile phones that are using SMS will be operating in the licensed spectrum space. Mobile phones that are using WAP, HTTP, web Services, or thick client applications may be operating either in the licensed spectrum space, or the unlicensed spectrum space using technologies similar to the 802.11b specifications for wireless LAN’s. To this extent, every other device identified in this research (e.g. proprietary clickers, PDA’s, laptops, netbooks) is likely to use the unlicensed spectrum.

**Delivery Layer**

The purpose of this layer is to provide a semantic structure to encapsulate the message that is being sent, and a set of protocols that will ensure reliable message delivery. Options include SMS, WAP, MMS, HTTP, web services, eMail and rFreq. rFreq represents the proprietary delivery format used in most clicker systems. This delivery option is specific to each vendor and systems are not interoperable.

**Application Layer**

The purpose of this layer is to receive the message from the delivery layer, provide any analytical processing, and storage for subsequent offline processing and analysis. In the case of a simple polling system, the application layer would ensure that the message was specified correctly for an actual and current poll, that the voting option was valid, and determine if multiple polling was being facilitated. In the case of using mobile learning within an exercise utilizing participatory simulation, the application might prompt the user with information requiring an interaction or conversation between learning and environment, or perhaps in a shared capacity, allow information from other users to be viewable. While polling or voting applications could be viewed as a generic application category, the m-learning activities that support other learning strategies (e.g. participatory simulation, context awareness, collaborative learning), are normally unique application instances. Typically there is a tight coupling between layers 1 (platform) through to layer 5 (presentation) for most personal response systems. Different platform choices take mutually exclusive vertical tracks. This has led to the problem that has been identified where a system that has been designed to allow learners to use SMS at the delivery layer, is not integrated or flexible enough, to accommodate other platform options (eg netbooks), using a different delivery option (e.g. HTTP), for the same instance of a learning activity session (e.g. a poll).

**Delivery-To-Application Middleware**

The solution to this problem is to ensure that the application architecture incorporates a sub layer to support simultaneous delivery options.

Figure 2 (below) shows how the layered model for mobile PRS integrates multiple options in layer 1, the platform layer, layer 2, the transport layer, and layer 3, the delivery layer. The delivery to application layer allows a single application to access inputs from multiple devices as well as sending data through any of the available delivery, transport and platform options.

![Figure 2: Flexible platform-to-delivery architecture](image)
**Presentation Layer**
The presentation layer of the layered model for extensible mobile PRS should accommodate and recognise how different visualisation modes support the computational and analytical objectives of the presentation layer, and also support the different learning paradigms and classroom teaching objectives, intended by the instructor for the current activity. The following characteristics are necessary for the presentation layer; multiple visualization modes, process independence and dynamic updating.

**Learning Layer**
The purpose of this layer is to connect the technology layers with the goal of informing the instructor on how established theories from the study of learning, can be made applicable and relevant to the education environment of m-learning. We will first discuss how the learning layer supports major areas of learning relevant to mobile technologies, and then we will discuss how the new ideas of Web 2.0 are accessible from the layered model. Naismith et al. (2004) identified six main themes and classifications for areas of learning. We summarize some of the specific examples of mobile technology presented from that research and how they support specific learning styles.

<table>
<thead>
<tr>
<th>Learning Style</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviourist</td>
<td>Constructing activities where the use of polling students with questions, or voting on ideas is the most obvious example from the mobile technology arena to support this style.</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Rather than the learner taking on the role of the observer, constructivist learning is enabled by the learning being part of, or acting out, or immersing in the phenomenon under study.</td>
</tr>
<tr>
<td>Situated Learning</td>
<td>This requires that learning is presented in an authentic context and an example of how mobile technologies support this can be seen by the many context-aware applications and their usages.</td>
</tr>
<tr>
<td>Collaborative Learning</td>
<td>Rather than every individual responding, mobile devices can accommodate learners teaming up and promoting interaction among peers and encouraging discussion, before sending responses back for a class wide view.</td>
</tr>
<tr>
<td>Lifelong and Informal Learning</td>
<td>Informal learning by definition is not a prescribed activity by the instructor, but it is founded on the assumption that mobile technologies, where they are sufficiently small and unobtrusive, can blend into everyday activity and support learning in either deliberate or unintended ways.</td>
</tr>
<tr>
<td>Learning and Teaching support</td>
<td>Mobile devices can contribute in multiple dimensions in this area. From learners having up-to-date notification of course activities, assessment results, or communication</td>
</tr>
</tbody>
</table>

**Table 2: Learning styles applied to mobile technology**

The second part of the learning layer addresses how the new ideas from Web 2.0 can be integrated into the mental model. In this particular case, utilizing these new ideas is optional in this layer. We can see how the presentation layer might directly support any of the 6 learning styles discussed above, or how it might support one of the key ideas in education of Web 2.0, and then this could be part of the teaching plan to achieve a particular learning style.

Some of the key ideas behind Web 2.0 are the impact that social networking, tagging, user generated content and new levels of interactivity have on the way knowledge is being acquired. Social networking can be supported in a mobile learning environment because drills, feedback, content and observations can be shared on a blogging site rather than limited to in-class or a forum channel. Posting recorded lectures or other resources and then allowing students to tag in an unrestricted way, could provide more valuable insights than alternatives of uploading to a designated learning management system and having the resource stored under a strict categorisation system.

Allowing discussions to continue out of the classroom and applying the mobile examples of
constructivist learning provide a meaningful context for leveraging user generated content. Audio blogs, podcasts, micro blogging and rich media formats are all accessible via a mobile technology environment and could also support new levels of interactivity.

**DSR Mobile PRS - Application**

This section describes a classroom experiment using this framework and the Mobile PRS application. Recalling the scenario that was presented above, the context for this demonstration is to have students respond to a series of questions that has been set up through a classroom response system. The demonstration requires different users being able to answer the same question, at the same time, with different physical response devices.

The first context for this experiment is that mobile PRS allows learners to participate through texting in the case of classroom response systems, however students with netbooks, laptops or PDA’s cannot participate because the delivery system being used in mobile SMS.

The second context for the demonstration is to allow learners in the classroom the ability to contribute messages and discussions through any of the physical response devices, and to have these messages delivered directly to one of the Web 2.0 services namely a micro blogging site called twitter. These messages will be available to the class outside of the lecture session, allowing students to reflect and build on their learning experience, through the same message loops described by Markett (2006).

**Demo1: Layer 1 – Platform**

A representation of various devices that have been used in actual classroom environments is listed in Table 3. In all cases, the students were able to participate in the activity regardless of what type of device they had.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Specifications</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Phone</td>
<td>GSM 900 / 1800 / 1900 GPRS/HSCSD/EDGE/Bluetooth/irDA SMS, MMS, Email, Instant Messaging WAP 2.0/xHTML Java</td>
<td>2G network capable Limited screen size of 5 lines</td>
</tr>
<tr>
<td>Nokia 6230</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDA</td>
<td>GSM 850 / 900 / 1800 / 1900 HSDPA 2100 GPRS/EDGE/3G/WLAN/Bluetooth SMS, EMS, MMS, Email, Instant Message WAP 2.0/xHTML, HTML, RSS feeds Java OS – Windows Mobile 6.5.1</td>
<td>3G network capable Full PDA and large 240x400 screen</td>
</tr>
<tr>
<td>Samsung i900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laptop</td>
<td>1.73GHz processor Pentium M ATI Radeon graphics 14’ screen size OS – Win XP Professional Wireless LAN</td>
<td>Medium range laptop Full wired and wireless access</td>
</tr>
<tr>
<td>Toshiba M50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Heterogeneous platform specifications

**Demo1: Layer 2 – Transport**

Each of the platforms was set up to use a separate transport mechanism described in Table 4.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Transport</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Phone</td>
<td>GSM 900 / 1800 / 1900</td>
<td>Standard carrier to carry audio phone conversations, and GSM network integrates message sublayer for short message service (SMS)</td>
</tr>
<tr>
<td>Nokia 6230</td>
<td>GSM</td>
<td>-</td>
</tr>
<tr>
<td>PDA</td>
<td>GSM / GPRS</td>
<td>General packet radio service is a service provided by mobile communication carriers to provide a packet</td>
</tr>
<tr>
<td>Samsung i900</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
The mobile PRS architecture presented in Figure 1 must have a number of transport receiver mechanisms to accommodate the desired transport layer being used. Where multiple transport layers are in use, multiple mechanisms must co-exist for the solution to be fully integrated. In this demonstration, there are two transport mechanisms. One mechanism is required to receive GSM mobile network signals. In this particular case, this is provided by connecting an additional mobile phone directly to the lecturer’s laptop and polling this laptop every second to determine if any new messages have arrived. The second transport mechanism required is a LAN connection for the laptop. Using the LAN connection, the delivery-to-application middleware software can be triggered for both the transport options of 802.11g and GSM/WAP (NB: GSM/WAP will update the system through the delivery-to-application middleware).

**Demo1: Layer 3 – Delivery**

Various delivery layer options were used in this demonstration; SMS, WAP and HTTP. As a delivery option, SMS is limited to 160 characters and each transmission is independent in context and scope to subsequent messages. WAP and HTTP provide higher levels of message complexity. SMS, WAP and HTTP are all protocol specifications that address the semantics, syntax, timing and functional requirements of standard messaging systems within a data communication context.

**Demo1: Layer 4 – Application**

a) Delivery-To-Application Sub-Layer

This component of the layered mobile PRS architecture is written in PHP v5.2.0 and running on a Windows XP Profession operating system. It is a stub application that reads a configuration file that can be modified to represent the various delivery options to be accommodated (e.g. SMS, HTTP, irDA). Each delivery option can have one or more associated transfer processes (e.g. where SMS is the delivery option, the associated transfer process could be via a SMS gateway provider, or it could be via an actual mobile phone handset connected to the lecturer’s laptop). To ensure a robust system, each of the transfer processes is initiated and forked to run in the background as separate instances of PHP programs.

b) SMS_transfer_local

The Transport receiver has been set up to facilitate three transport mechanisms. One of these is the capability of having a mobile phone handset acting as a receiver connected to a laptop. In this case an open source application called GammuW is used to continuously poll the phone and copy the texts received into the designated folder. The job of SMS_transfer_local is to continually poll the SMS text message target folder, and forward to the mobile PRS database in an appropriate form.

HTTP_transport

The other two transport mechanisms that have been set up are the WAN connector and the LAN connector via the institutions wireless network which provides connectivity to the laptop. The job of HTTP_transport is to initiate one or more web based services that could accommodate various web and Web 2.0 applications. In this example, one instance of HTTP_transport is to initiate an HTTP apache web server, to make available, simultaneous access to the polls via the laptop using HTTP, or via the PDA using a WAP gateway also setup on the server. Another instance of HTTP_transport creates a gateway for text based messages to be transferred directly to Web 2.0 applications, and in this case, the one that has been configured is twitter.

From the learner’s perspective, we can see that the following response devices all have access to the same in-classroom poll, all with slightly different views and forms of access (Table 5).

| Class Poll | 131 | wap.isom.ac.nz/131 | http://www.isom.ac.nz/131 |
| Class Discussion | wn d we cvr that | When did we cover that | When did we cover that |

Table 5: User input options for response devices
Application

In this example the application logic is to process the messages coming from the delivery-to-application sublayer. For the case of a classroom response system, options for allowing multiple votes, automatic responses to votes, customised replies based on specific response options, selection of poll or question to be displayed, are all necessary functions to be accommodated. In the case of Web 2.0, the logic could include which twitter lists should the message be sent, and possibly based on user, keyword, and time.

The application logic is parameterised via a Delphi Win32 console program to allow the instructor a quick and simple interface to select how the application is intended to be used.

Demo1: Layer 5 – Presentation

The n-tiered software design is strengthened by the separation of the visualization component from the application logic. It is also dynamically configurable by the instructor at run time, although a more typical scenario is that the presentation style will be decided before the start of the lesson. The following screen captures (Figure 5), show how the presentation of a simple poll could be displayed in multiple views, and shows how the display of the twitter discussion and conversation can actually compliment the polling activity lesson, or it could be displayed as a separate view.

For SMS text based entry into twitter, the login account is a general account, in this case ktawa. Each source, or specific response device is allocated a unique ID to track a discussion. Hence we see that user ‘476’ above has responded with two separate questions.

Users with a laptop may actually have their own twitter account and be logged in and send messages under their actual username. For users of mobile phones and SMS, or for PDA/laptop users accessing through WAP or generic HTTP delivery options, a unique ID is a coded representation of the mobile phone number, or the user account (NB: Students must be authenticated before wireless intranet services are made available). This can be used for the ongoing tracking of conversations over multiple classes.
Demo1: Layer 6 – Learning

There are at least two learning paradigms supported by these two activities. One is the Behaviourist approach where the act of participating in the poll or quiz creates an initial stimulus for the learner. This engagement focuses the student’s attention and draws them into a context for active participation. The learner can respond to the poll and is provided with instantaneous feedback of how other students are processing the information. It provides the instructor with instantaneous feedback on how well the learning concept is being understood.

The second learning approach being supported is a Collaborative learning paradigm (Vygotsky & Cole, 1978). The twitter application involves a series of interactions that learners share in the context of a continuous conversation. The messages, while identified by thread, do not reveal the user, and students can remain anonymous if they choose (NB: Laptop and PDA users might log into a full twitter software application and use actual account names, which may or may not reveal their identity in a classroom environment).

For Web 2.0, the education perspective is one of active participation and interactivity through the use of social networks and micro-blogging. Twitter takes the discussion out of the classroom and into the realm where students are generally conversing. The discussion of any particular topic could be enhanced by numerous contributions, both of enrolled students, and to a broader audience as well. Both the twitter feed and any additional course resources could be availed to tagging and social bookmarking options. This would allow the students to decide an appropriate classification for the content, and reveal nuances in understanding and appreciation, of the course concepts.

Conclusions and Discussion

In a rapidly changing digital environment, teachers and educators must continue to adapt so that teaching and learning styles are in sync with the current norms and expectations of the new millennium learners. From the laundry list of best practice teaching attributes, some of which include informative, challenging, engaging, motivating, empowering, and enlightening, one attribute that has a particular resonance in this context, is that the process of learning must be relevant. It is abundantly evident that Web 2.0 has had a significant impact on how people acquire knowledge, how knowledge is consumed, and how it is constructed. This mindset and behavioural change overlaps not only with how our society shapes and forms itself, it overlaps with the very core of the learning process.

The key contribution of this research is the artifact produced by the DSR methodology in the form of the layered model for extensible mobile PRS. It provides a mental model for the instructor and institution to examine how teaching and learning might be informed in a mobile learning environment. The benefits are listed as follows:

- Mental model of the m-learning domain
- Connects the technology environment with the learning environment
- Provides a framework for understanding how to include the new ideas in education being availed by the emergence of Web 2.0 services.
- Addresses a heterogeneous platform of end user response devices for simultaneous active participation.

As evidence to the incremental dimension of the design process, this approach provides a basis for future exploration in a range of concepts.

- Transferring the domain: It is an interesting proposition to see how the technology layer could be inserted into different domains.
- Presentation modality: During this research, a number of requests were made for various options for the mode of presentation used. Specifically one colleague was interested in a gauge/dial view that could be used to represent student satisfaction of the lecture delivery in real time. An alternate construct might be the use of continuous line graph, changing in response to students’ satisfaction/dissatisfaction of the lecture. There are numerous behavioural studies and future research that could explore the inter-relationships on this type of feedback immediacy.
- Qualitative research: This could be initiated to explore the degree of self-constructed content and knowledge that is actually contributed by students in the simple case of combining micro-blogs and social networking sites like twitter in the lecture delivery.

It is likely that we have yet to understand fully how learning will continue to be influenced by the current set of Web 2.0 services. One thing is certain, there will be many opportunities for research in the future.
References


