# Chapter 10
# Use of Dashboards and Visualization Techniques to Support Teacher Decision Making

**Alex Mottus, Kinshuk, Sabine Graf and Nian-Shing Chen**

**Abstract** Learning environments have evolved rapidly in the past decade growing the encompass Learning Management Systems, rich digital content, and multiple forms of access including new mobile technologies. In the process students have moved further and further away from traditional classrooms where teachers have historically provided face-to-face learning content and supports. Digital information sources have vastly exceeded the capacity of any one content specialist but learning supports have been harder to establish in a decentralized education model. Communication methods have become moved to asynchronous types in the form of e-mail, texts, and discussion forums. This has left teachers with a serious disconnect that has not, as yet, been reconciled by technology or methodology. This indicates a gap which learning environments and teachers' alike need to bridge before ubiquitous learning environments can fully achieve the goal of successfully meeting learner needs outside of the classroom paradigm.

**Keywords** Ubiquitous learning · Interactive dashboard · Teacher support system

## 10.1 Introduction

The world has undergone radical changes in the past 100 years as new technologies have reshaped the face of the culture, industry, and even human interaction. Strangely over the same period, educational institutions, and teaching mechanisms have remained largely unchanged until relatively recently. With the advent of the

A. Mottus (✉)
Pembina Hills Regional School Division #7, 5310-49 Str, Barrhead, AB T7N 1P3, Canada
e-mail: alexmottus@gmail.com

Kinshuk · S. Graf
Athabasca University, Edmonton, Alberta, Canada

N.-S. Chen
National Sun Yat-sen University, Kaohsiung, Taiwan

 
Kinshuk and R. Huang (eds.), *Ubiquitous Learning Environments and Technologies*,
Lecture Notes in Educational Technology, DOI 10.1007/978-3-662-44659-1_10

Internet combined with an explosion in the prevalence of home computers, personal devices, and readily available network connectivity the very bedrock of education has sustained a significant shift. In today's world, educational opportunities abound both in digital and physical formats that can be utilized at any time under a vast range of circumstances. Education is no longer bound to a physical location as handheld network devices have become commonplace, allowing students to not only access, but in turn, create content that can be interacted with directly and socially. This has created a fully ubiquitous learning environment which students are now immersed in by means of devices that are available 24/7. This has been reflected in educational environments as hybrid courses which combine online and real-world aspects have quickly become the majority of post-secondary offerings (Li 2009). The introduction of real time connectivity has also added location and media supports that can tie directly to physical elements unlocking the full potential of real-world learning objects. This is a dramatic departure from classroom-based education which dominated the last century where teachers led content delivery as well as learning support. In a current scenario, learning artifacts can be found in anywhere at the tap of a finger providing students with more choice than they could ever effectively consume. Ironically, this has become part of the problem as educational opportunities can become overwhelming by their sheer quantity. It is also notable the other key role of teachers, that of providing learning support, has been compromised in most ubiquitous learning environments. This stems from the fact that teachers and students no longer need to share the same physical proximity as learning has moved outside the classroom and, in extreme situations, even around the world. This means that teachers can no longer rely on direct observation to monitor students and identify learning challenges. Instead it is possible and even probable, that a teacher may not be aware of what their students are doing at any given time. While that may not be an issue on a regular basis it can create serious impediments when learning problems arise. An example would be a student who has been unable to develop a competency because they can't find a suitable resource or explanation. Normally they would simply ask a teacher for help but in a distance or distributed learning scenario that teacher might not be available or the student might not know how to make contact appropriately.

The absence of teacher support is compounded by the fact that ubiquitous learning situations also tend to have a much higher student to teacher ration making instructional time much or precious. In order to mitigate the challenges provided by such a situation it makes sense to leverage the skills which teachers have developed over the years. However, to do so, they need some way to reconnect with their students in a timely and effective manner that can provide a teacher with operational knowledge as well as learning options. This challenge is further complicated by the learning process itself. While many automated systems take a transactional approach to problems that can be extremely difficult to accomplish with knowledge acquisition. The primary problem is that learning is by its very nature an internal process, meaning that it has to be evaluated by external methods. This can be prone to errors created by the metrics, tools, and methods used to measure knowledge levels. Learning is also seldom incremental meaning that simply spending time on a task is no guarantee of success. Instead learning can often occur in stops and starts which may not correspond to any predefined pattern. This suggests a reliance on constant monitoring and the evaluation of educational processes in order to properly support and enhance student learning.

One possible solution to the problems outlined is to develop a tool specifically for teacher use. This would capture and display student information in a way that is accessible and meaningful. This includes the need to aggregate complex data structures in a way that is friendly and easy to use. Visualization techniques have been used extensively to provide supports to domain specialists who may not have particular expertise in information technology (Lavrac et al. 2007). That type of approach has been evidenced in commercial and scientific tools which have rendered large amounts of decision support information in dashboard formats. Likewise this type of tool has been used in Learning Management Systems (LMS) and Student Information Systems (SIS) but on a very basic level. Normally these tools focus on specific metrics that are directly tied to the application they support. In this discussion, a dashboard approach would need to illustrate a global environment by consuming and displaying educational information regarding as many aspects of student activity as possible. Finally, it would need a recommendation component to provide teachers with options, drawing on possibilities as broad as those their students are utilizing in learning. In this way it should become possible for ubiquitous learning to be effectively supported while students enjoy all the advantages of rich and infinitely diverse educational choices.

## 10.2 Review of Learning Supports

Before starting to explore tools and other solutions it is important to take a look at the various options that have been researched to provide students with supports in today's learning environments. These range from automated approaches to those based on examining information sources to explore learning activities. In most of these instances, teachers or educational researchers take an active role in development but have varying degree of interaction in the actual use of learning support methods. An interesting contrast in much of this research has to do with whether it seeks to replicate or support teacher function. Work in this area is seldom black or white but instead exists along a spectrum between the two extremes. This provides a good set of different results taken from the various methods.

One of the leading areas of research aimed at automating teaching activities revolves around the work on Intelligent Tutors. This type of mechanism has been utilized in a number of different domain areas to deliver educational services on demand without the need to have a teacher present. Generally, Intelligent Tutors have been shown to result in good success rates with positive feedback from students (Mitrovic 2006). They are normally built with the assistance of domain specialists and educators to try and replicate the learning process as closely as possible. This style of learning support has the advantage of providing students with near instant feedback and by supplying tools for dealing with previously identified problems. The challenge of these systems is that they tend to be very complex requiring extensive programming to create and maintain. This has proven very time consuming even with experimental work on automated interviewing methods for capturing knowledge and skills from human domain experts (Hwang et al. 2011). They are also domain specific meaning that they are focused on specific knowledge areas making them difficult to modify for other purposes. They are also built for specific problems and scenarios meaning they may not be able to adapt to new learning challenges. Other methodologies such as using constraints and fuzzy logic to make ITS systems more generic have simplified the programming but not enough to make them realistic on a large scale (Mitrovic et al. 2007). While they may be paired with more traditional teaching methods this still leaves a gap in that they are difficult to modify meaning that, even if teachers identify new approaches, they are unlikely to be able to implement them.

Another automated approach comes in the form of learning companions which are a more social tool that seeks to pair learners with an automated system. This methodology has been shown to reduce learner confusion in virtual environments resulting in better outcomes. These systems also seek to address the social aspect of learning as they provide individual students with a source of communication that they can use to develop new ideas (Wu et al. 2012). These can exist in a number of different formats as the companion may function as another student, a teacher, or even as a friend. These different variations provide flexibility in terms of approach as the can be used to evaluate as well as assist students. While they are certainly useful, there are limitations to how much impact they can have on the learning process. In some cases they are used as a supplementary component for modeling and ITS approaches (Limoanco and Sison 2002). They provide a supplement to an existing program of study adding a social component which can be available any time a student enters the "system". Once again the programming involved in these tools is specialized and in most cases would be beyond most teachers' ability to customize. This creates another situation that makes adaptation difficult and requires the use of some sort of human intervention to handle unique scenarios.

The automated tools can make use out of student information but the purest form of that research comes from Educational Data Mining (EDM) and Learning Analytics. These fields leverage previous research in scientific and business data mining but take an education centric focus to develop techniques specialized for working with student and learning information. Research has shown that these types of systems have been highly effective at evaluating student progress and determining what content best suits a learners needs (Hatzilygeroudis et al. 2005). EDM and LA initiatives have also developed a number of different algorithms and heuristics for extracting complex data patterns from vast repositories of information that would otherwise be nonsensical. In many of these cases, the sheer volume of information can be overwhelming rendering it effectively useless. This is a significant problem given the prevalence of information now available from SIS, LMS, and web logs representing all kinds of student activities. From these sources rich outcomes can be drawn such as developing learning styles and preferences which can be used to customize and delivery educational content. Unfortunately, these tools once again represent a high degree of specialization requiring training and years of practice to use effectively. In the case of teachers this detracts from instructional time and forces them to develop an entirely new skills set to simply access the information. Instead it makes much more sense to allow them to consume the outcomes or develop questions that can be sourced by other tools or specialists. To make these outcomes more useful it also makes sense to render them in a way that is easier to understand and manipulate. Elements of LA have focused on this problem turning to visualization techniques to provide information in a way that can easily be interpreted and used. Like the dashboards seen in the LMS they do tend to be more localized focused on specific outcomes rather than a holistic approach. This suggests that while the approach has considerable value there is still work remaining to be done to deal with a fully ubiquitous scenario. There has also been research completed to support the belief that there is general a need for the increased use of visualizations in data analysis (Ali et al. 2012).

As mentioned in the introduction one of the challenges of working in distributed or distance learning environment is the ability to gain awareness of student activities. This is perhaps the most critical for those students in need who have either encountered a learning difficulty or have ceased to be engaged. Ideally any such process would locate students before reaching a critical point at which a student begins to fail or ceases to be engaged. An example of work in this area was provided by the Signals project at Purdue where researchers explored student data to attempt to identify those who were at risk (Arnold et al. 2010). Likewise Macfadyen et al. provided a proof of concept for a similar system in order to find students with risk attributes (Macfadyen and Dawson 2010). Both of these cases focused on a fairly Boolean concept but one that could be invaluable to a teacher trying to prioritized the need levels of their students. In turn this suggests that a high-level overview of student information could prove valuable by quickly supplying information. This has been expressed in the form of dashboard tools which have proved useful for administrative leaders as the make key operational decisions (Lavrac et al. 2007). Dashboards have been utilized with great success in business, health case, and operations to both consolidate and display datasets. Given the complex and dynamic nature of student information it would seem reasonable to a similar approach would be helpful to teachers monitoring and assisting students who they might have no direct contact with.

In all of these examples educational expertise is critical to developing a solution for supporting student learning. While automated approaches provide excellent supplements they essentially replicate teacher function which can be very complex and difficult to achieve. Instead a hybrid solution seems more likely to succeed at least in the short team. In terms of data mining, there are endless possibilities but this information must be accessible and usable to be able to make a different in a real time learning context. Thus, a teacher support tools seems logical to allow teachers to find and support students using a variety of content and supports. The ubiquitous nature of learning makes this even more necessary to avoid simply overwhelming teachers with details and making decision processes impossibly complex.

## 10.3 Teacher Tools Requirements

While a formal set of requirements are difficult to ascertain at this point it is possible to draw out high-level details that can be used to construct a prototype design. The literature review has already identified some important trends that have driven research in student learning and supporting educational mechanisms in a non-classroom environment. Specifically, these would include providing timely support and refining information for use in customizing learning environments. In some ways these two requirements can be at odds with each other as one is immediate while the latter can require large amounts of processing time to achieve the appropriate outcomes. This suggests a hybrid strategy which can split information into different categories which can be handled differently but in conjunction with one another. In other words, information being displayed can be real time or aggregated but related by a common thread such as student preferences. In this example, immediate data may show what a student is currently engaged in but in the context of their preferences, a determination can be based on large collections of aggregated data.

Awareness of student states or conditions is most commonly expressed by risk assessments which determine whether or not a specific learner needs immediate assistance. This concept has been explored in previous research (Arnold et al. 2010) but not necessarily in terms of a ubiquitous environment which presents a highly malleable scenario with numerous inputs but potentially a lack of formal structure. This suggests the importance of context to give teachers not only just the “what” but also the “how” and the “where” their students are experiencing difficulty. This also needs to be able to drive navigation to allow teachers to access additional details and even recommendations to assist with their teaching practice. This speaks directly to the need to provide teachers with relevant information but in a timely fashion that can be utilized immediately. This can be seen as similar to automated approaches which seek to provide immediate feedback but those are based on defined problems and learning situations. In the proposed case, the teacher can act as a mediator who can use previous experience and knowledge to evaluate student needs in real time and provide solutions. This makes support mechanisms much more flexible as they no longer need to rely on predefined scenarios which have been programmatically rendered.

Once, a specific student has been selected it is critical that a teacher can get a full picture of what that student is doing, what environment they are in, and what resources and problems they are exposed to. This implies a highly complex dataset which lends itself to the use of visualization techniques to make information more accessible and efficient to digest. This needs to communicate a summary of the potential factors that a student can encounter in a ubiquitous learning environment. Location data and a cataloging of the learning objects and opportunities in a geographical area represent a new challenge and highlight the absence of physical contact between teacher and student. Specific student information about learning styles, preferences, and knowledge levels begin to augment and replace the direct evaluation processes that are a normal part of classroom education. This can then drive recommendations by providing a context which allows teachers to understand a student's needs and make informed decisions leveraging their own expertise in combination with relevant data.

A complementary approach is the ability to search and determine patterns based on collective data which involves entire classes or identified subsets. In this type of situation, a teacher can search for outliers or unique patterns that may not have been flagged by the system. This allows the teacher to use their own knowledge and expertise to drive investigative processes which locate student issues and lead to improvements in educational delivery. For this approach, information needs to be common to the group in terms of their behavior, progress, or results. This is to allow for effective comparison of larger groups which can the subsequently be used to create a subset to allow teachers to draw out smaller working groups or specific individuals. The flow from large class groups to smaller groups sharing certain attributes needs to be seamless allowing teachers to once again move quickly and efficiently between different functional areas. These would need to be treated slightly differently as summary visualization tend to focus on trends and larger patterns where smaller groups can use techniques to directly compare students in groups of 10 or less. This is to avoid providing overwhelming data which can hide key points within larger bodies of information. From an operational point of view, trends and status updates are both important aspects which have provided tool users with a real time awareness of where the information they are monitoring is going (Mahendrawathi et al. 2010). The identification of exceptions has also proved important as those elements which stray outside the norm can offer quick flags as to what is going wrong or identifying new patterns that may be emerging (Sachin and Vijay 2012).

Due to the variability of such an environment it also makes sense to allow teachers the ability to customize and manipulate visualizations in order to meet as broad a range of possibilities as possible. This still needs to be done within a clear and concise, point, and click interface which can easily be learned based on transferable skills from other applications. While this environment puts a high emphasis on data use and manipulation the purpose is to create an abstraction between data consumption and data mining construction. This means that the programming around data aggregation and defining useful patterns is out of the scope of this discussion even though it is critically important. Instead an optimal situation is portrayed in which information is readily available which can be manipulated with a standardized interface.

## 10.4 Development Environment

As the support of teachers turns to technology considerations there are a range of different possibilities to consider. Many dashboards are simply add-ons to a larger tool which they directly support. For examples, most LMS have a dashboard component which has been built with the same programming language and architectural concern patterns. Since, the proposed solution is ambivalent toward specific tools it becomes much easier to make choices which support ease of use, open access to technology, and the ability to easily change or modify toolsets. In the context of a ubiquitous approach, it is logical to take a community approach which would allow researchers and practitioners from any area to utilize a final project. These ideals promote a source approach which provides full access to both source code and documentation. As with many LMS it also suggests a web-based approach which is platform independent but with a focus on selecting industry standard and community supported toolsets. To this end, the use of HTML5 and JavaScript-based technologies makes excellent sense as these areas represent the natural evolution of Internet technologies in a format that is accessible to developers and users alike. A quick survey of the open sources community also reveals a plethora of JavaScript visualization libraries that offer a broad range of techniques and functions (Google Developers 2013; Graph Visualization Library With jQuery—Arbor 2013; Introduction to Using Chart Tools 2013).

## 10.5 Technical Details

In terms of specific tools, there are some clear choices that can be used to form the backbone of the development environment. From a data repository perspective there needs to be an intermediary location which can be used to refine data elements. This approach was selected to reduce the real-time overhead needed to present data elements drawn from data mining activities. Previous research has explored this topic looking at data structures that can be used to collect information from different sources (Yang et al. 2010). In the example provided here the Personalized Adaptive Dashboard (PALD) illustrates this idea and has been used as a local repository to house information suited toward a dashboard function

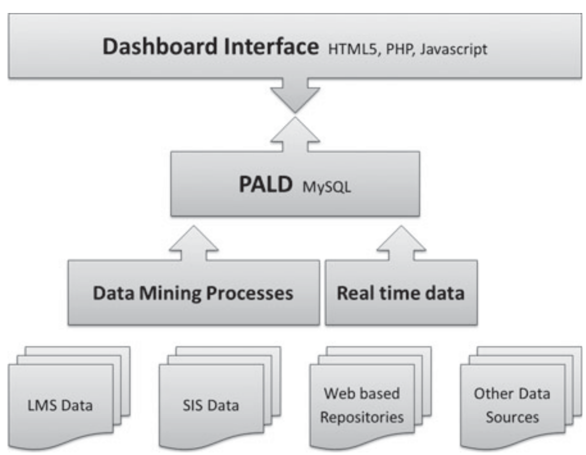


**Fig. 10.1** Architecture diagram

(Fig. 10.1). The use of PALD can be expressed from an implementation perspective by either MySQL (Oracle Corporation 2013) or PostgreSQL (The PostgreSQL Global Development Group 2013) offer robust solutions that can be used easily at a very low cost.

Web servers are also freely available although the Apache Foundation offers one of the most commonly utilized which comes with a number of plug-in options including PHP (The Apache Software Foundation 2012). The latter is an important consideration as it offers a highly flexible technology option for manipulating data and providing dynamic content. While HTML5 and JavaScript may be better suited for a final implementation, PHP can be used accelerate the prototyping process based on its ease of use. Finally, from a visualization perspective three leading candidates can be drawn from the rich JavaScript library community to provide mechanisms for rendering information in highly salient manner. Of these the Google API emerges as the most suitable for prototyping as it contains excellent documentation, a rich collection of functions and the ability to manipulate data in a modular fashion which can be shared between objects. With these tools at hand it is possible to engage in a functional prototyping exercise to illustrate what elements an educational decision support tool could and should have.

In terms of actual construction, there is an interesting dichotomy between the need for elements which are standalone and yet interrelated. Discrete data collections related to a specific subject such as knowledge levels would need to be displayed in such a way that they could provide insight on their own. At the same time, it should also be possible to connect to visualizations of other data elements such as learning object preferences and learning styles. In a highly mature example it would be ideal to be able to select a knowledge level and automatically subset to the learning objects used to develop that understanding. One way to approach this type of functionality is based on a "widget" style of development where individual visualizations can be built as unique modules in terms of function and interface. It is possible to add and remove these items from the parent display and related them to the other widgets based on underlying data. This provides a highly flexible framework which can be used to display any number of items which can be customized in terms of selection. Thus, widgets could be built individually and then made available to larger dashboard by means of dropdowns or other screen management functionality.

## 10.6 Proposed Model

In terms of creating a working example a tabular interface provides a mechanism for cleanly dividing functions while simplifying navigation and workflow. Based on the requirements outlined earlier, four primary areas can be highlighted as providing a fundamental functionality. The first would be the at risk area which identifies students at risk and their categorization, next a focus on details specific to individual students, third information on the class cohort as a whole and finally a tab focused on specific groups extracted from the class. These form complementary areas which can flow from one tab to another as a teacher selects information and gains insights to enable them to make educational decisions.

The first case focuses on an "at risk" or overview tab in which information needs to be very timely and organized to draw a teacher's attention quickly. It also has to give them a high-level context of where students fit within a class. To do this different visualization elements have to be combined to provide a united interface which can drive follow up actions. The first visualizations need to organize students "in need" by category; in the example below (Fig. 10.2) students are flagged based on low social activity and prerequisites. There is another complementary grouping based on students who have stalled in their course work. A similar visualization also lists students who have self-identified by requesting help from the teacher along with the question or issue they are facing. At this point the teacher should be able to prioritize and focus their attention on a specific subset of students. This makes them more efficient and allows them to utilize the scare resource of instructional time in the most effective way possible. This is further enhanced with a real-time component which lists students as they become active or inactive in their learning environments. In the ubiquitous scenario proposed this could involve logging into an LMS, tweeting, or even using location technologies to recognize when a student enters a study area or physical learning object repository like a library. This gives the teacher an awareness of whether a student in need is

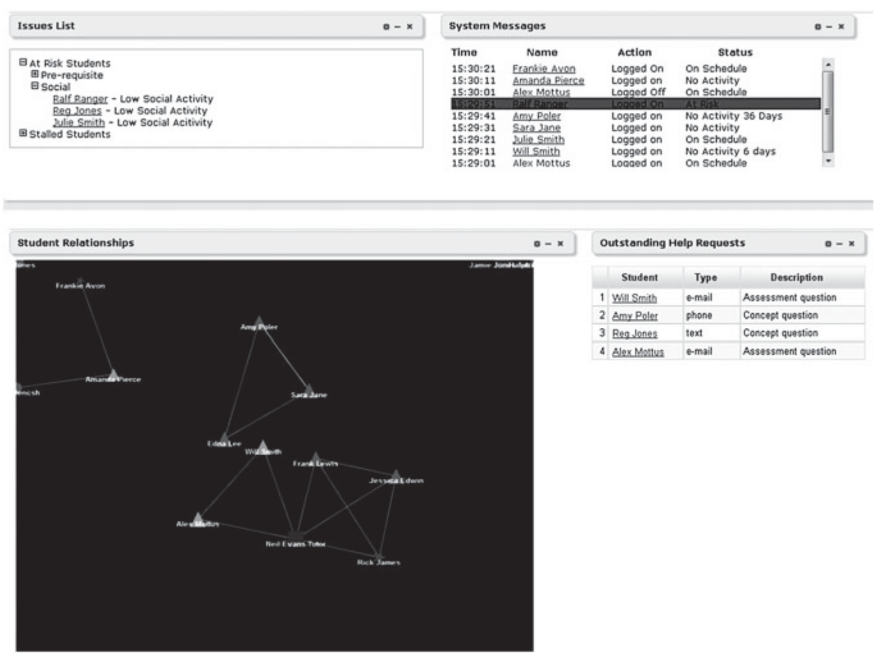


**Fig. 10.2** Screen design for an overview tab

accessible. This real-time logging feature provides additional visual cues by the using the color (red) to draw the teacher's attention when an "at risk" student becomes active. Finally, a node diagram is used to aggregate and relate a number of different elements to provide contextual information across groups of students in the class. This shows relationships as well as high-level attributes such as at risk categories and current performance in the class. In this way, the teacher can gain a high-level awareness at a glance. In all visualizations the student names are clickable to drive navigation and give the teacher the ability to quickly select individual students. In this manner the teacher can quickly identify, find and select a student so they can take immediate action.

In the second tab, the focus is on specific students where details can be aggregated and collected to provide insights on demographic, preference, location, and performance information. Student selection could be based on activities in other tabs such as choosing a student at risk or simply by working through a list of existing students examining traits and attributes. This supports workflow between tabs so that teachers can very quickly move from discovery to investigative to decision-making tasks. This is an important as factor as students in a ubiquitous environment are only available sporadically for direct interaction. In order to capitalize on these moments the teacher must be able to move quickly and efficiently between different activities. Once the teacher has selected a student they can be shown a data portrait of the student which gives them a much higher awareness of the student and their activities (García-Solórzano et al. 2012). Different elements can be observed in combination to show who students are, what they are doing, and how they prefer to learn (Fig. 10.3). By showing details like learning styles and preferences, teachers can determine which resources best suit a student's specific need (Graf et al. 2008). Location information can also indicate if physical learning objects or learning environments exist in the immediate area. These form the basis for providing supports and intervention opportunities from a content perspective. As mentioned earlier, ubiquitous environments provide a wealth of learning opportunities but not necessarily the details necessary to select which ones would best suit a certain learning situation. In this situation, the teacher can begin to use their own expertise to sort through options in the context of student information to form intervention plans and supports. Another benefit to location information is to be able to see whether other students and tutors exist in the area and who might be able to work collaboratively. This provides the ability to form social supports and groups which can augment learning and provide a richer experience. In terms of learning achievement, knowledge levels can be used to create concept maps of student's understanding, both in terms of performance and relating concepts. All of this supports a simple example of a functional recommendation mechanism which provides the teacher with an awareness of what options are available and allows them to select and provide feedback on how those actions work out. In this manner, the environment moves beyond information display and begins to create and collect its own actions for later feedback and support of decision-making processes.

The third tab takes a more exploratory view of student data by looking at classes as a whole. This collection of visualizations seeks to show different groupings

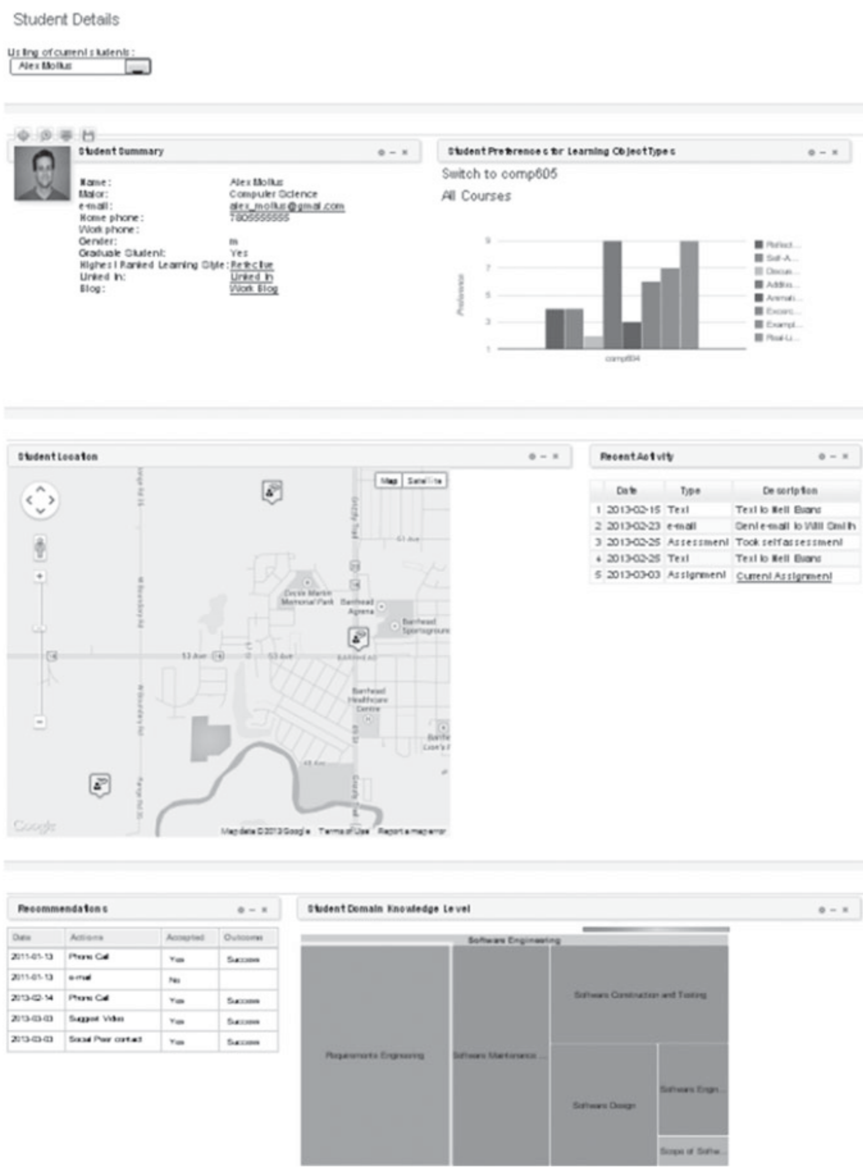


**Fig. 10.3** Screen design for student information tab

which comprise the full cohort of students. In order to avoid too much diversity, the groups of students are displayed based on distinct classes which can be selected from a drop down list at the top for the tab. This is helpful in situations where teachers may be supporting a set of different classes. The introduction of the “class” dataset also allows a teacher to use their own background and experiences to draw out specific patterns and find outliers. In the case of the overview tab, at risk students are brought to the teacher's attention but at the potential exclusion of other individuals who may also require assistance. Like the example of the Intelligent Tutors there are a fixed number of options which can be programed into the system. Thus, it makes sense to provide a flexible means for a teacher to be able to explore and identify groups and individuals based on their own observations. Assessment and progress information figure prominently as these are common items which can easily be compared and contrasted (Fig. 10.4). An example of a simple visualization would be to compare multiple assessments across different cohorts using graphing techniques (Friedler et al. 2008). Taking this one step, further each element, whether a piece of a pie chart or a block in bar diagram, becomes clickable to allow a teacher to quickly select and preload that group for further analysis in another tab. This creates easy navigation by surfacing distinct groups. Scattergrams also show student grouping or clusters which can be used to highlight outliers which form distinct plot points that can be clicked on to select specific students for the analysis described in the previous (student) tab. In this way, the teacher can choose how specific to get in terms of the number of students they want to analyze. Map visualizations also provide an excellent overview, especially in cases where students may be located in a variety of different cities and even countries. This can very quickly illustrate the diversity of a class and the challenges that students may face working with one another. One of the other potential challenges of manipulating this type of scenario stems from the fact students may be starting at different times during the calendar year. There are many examples of courses which are open intake which can create distinct cohorts within an individual class making it important to observer the rate at which students are proceeding through course materiel. This creates another opportunity for developing subsets and allowing teachers to observe different learning patterns.

The final tab focuses on groups of students who have been selected from the class visualizations in the previous tab or from a dropdown which displays predefined sets of students. The latter could be project groups generated by class activities who are working on the same assignment or subsets of students who are collaborating on various discussion groups. The differentiation of these two groups is quite important as the ability to provide recommendations can be a very intensive task from a computer processing perspective. That means it is extremely difficult to generate any sort of recommendations for Ad Hoc groups. Instead recommendations are only provided for predefined groups which can be analyzed in advance to generate solutions to potential learning problems (Fig. 10.4). In both cases the groups can be summarized as the same raw data can be leveraged to show progress, understanding, and learning preferences. In this way, a teacher can observe and work with groups collectively or once again drill down one more layers to work specifically with individual students. While this tab is quite similar to the class tab, it allows for greater detail and comparison in order to further analyze student activities and behavior. The bubble chart example in the top right corner (Fig. 10.5) illustrates this quite effectively as it combines a variety of different elements such as performance, progress, and learning styles. This is somewhat similar to the node

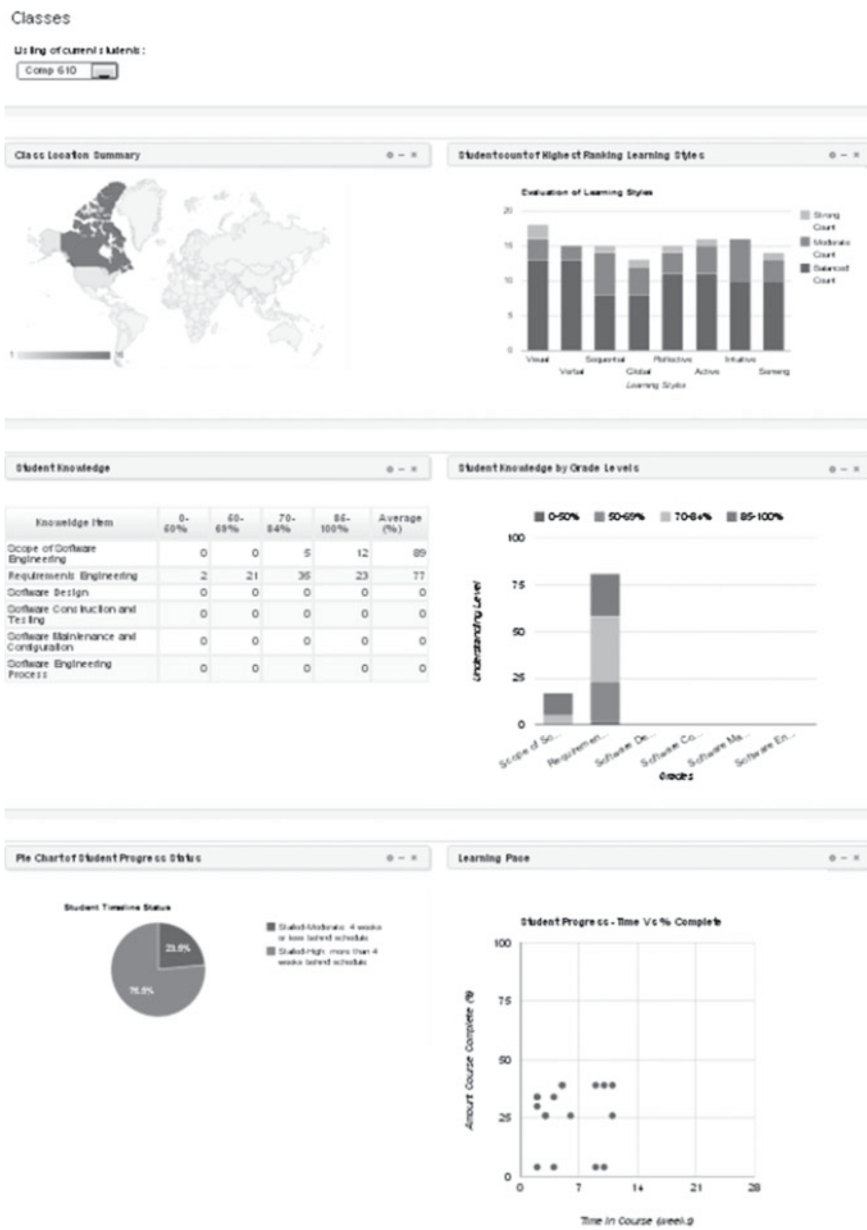


**Fig. 10.4** Screen design for a class tab

diagram presented in the overview tab. The goal of both these visualizations is quite similar as they provide a number of attributes which can be observed quickly in order for a teacher to gain understanding and make determinations about student need and potential solutions.

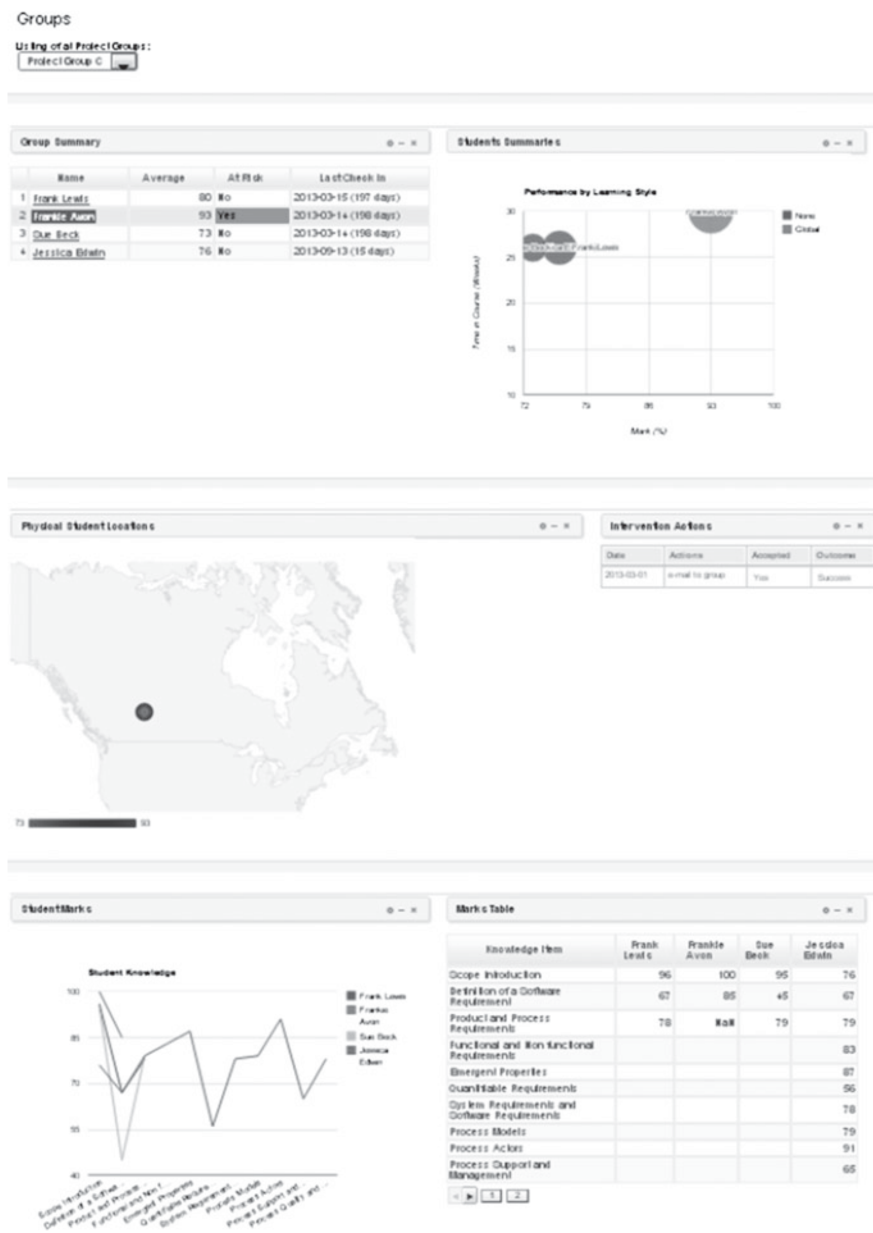

**Fig. 10.5** Screen design for a student groups tab

The proposed interface provides a working example of how a teacher might observe and work with information to find and assist students. It does this from both a system generated perspective and from a user driven mechanism which allows teacher to locate and generate the own groups based on personal experience and knowledge. This provides the best of machine and human intelligence by leveraging the strength of each. Workflow is designed to jump between tabs as teachers may need to move quickly from investigation to decision making as students come to their attention. This is aimed at maximizing teacher's time which become diffused in a ubiquitous learning environment. It should also allow them to make better decisions by providing contextual information which can focus on group and individual student's needs with the specific details of their learning scenarios.

## 10.7 Discussion

In examining student learning, a number of elements have emerged. While new supports have been developed to assist students there is still no comprehensive mechanism that can handle a fully ubiquitous environment. This can be problematic due to the complexities of the learning process and the vast number of options that students are presented with. Automated systems are already challenged when it comes to dealing with new scenarios and a variety of different domain knowledge sets. Likewise data analysis techniques are also constantly evolving to deal with problems related to managing vast data sets coming from a variety of different sources. The current trend is toward collecting more information about location and interaction details as new and more effective devices become available and are used by students and teachers. Managing all of these items suggests the need for a different approach which can leverage human intelligence in combination with machine. The proposed solution in this chapter takes this position as it demonstrates how a tool could be created to display information and assist a teacher in real time and for investigative purposes. This leverages the work done in automated and data analysis systems, while reintroducing the teacher as a critical agent in the learning process. In this situation, a teacher can utilize the benefits of highly complex components without requiring additional training or skills. The use of visualizations facilitates this by rendering information differently and in a range of alternate methods. This allows for customization which can allow for differentiated teaching as well as differentiating instruction methods. It also has the side benefit of increasing human interaction within ubiquitous learning by increasing the opportunity for teachers to interact with students in their classes. This stems from awareness as teachers can access information in order to simulate a face-to-face encounter which in term provides the ability to make connections. This can also provide an important validation mechanism for confirming automated actions which have generally been locked in machine driven systems (Mitrovic et al. 2007).

One of the other trends in technology as whole is the concept of integration which relates to systems becoming increasingly linked with one another. As this happens it also increases the complexity level as more and more factors begin to interact with one another. This draws a strong parallel to ubiquitous learning where different learning objects and systems are being to be drawn together to create a richer and more effecting educational environment. Much as with Executive Management Systems (EMS), educational decision making needs to be supported in order to make it accurate and flexible in the face of increasingly complex problems. As students encounter problems individually or collectively, strategies need to be implemented which can solve learning difficulties and provide resources that address a variety of challenges. This has the advantage of making teachers aware of what options actually exist for intervention or solution to problems. In the same way that a teacher may be unaware of details about a student, they may also be unfamiliar with the different supports that are in place, especially when learning environments become highly technical. In many cases, teachers are functioning as consumers of services themselves rather than creating different tools to help their students.

One of the key aspects of introducing new tools is that they become generators of information themselves. That is particularly true in a decision support system where choices can be captured in the context of specific problems. This creates the opportunity for creating an incredibly sophisticated source of data which draws on the expertise of teacher as they work with the learning process itself. This is an important factor as learning occurs in relative isolation within the mind of each student. There is really no way to directly measure it as a process as it must be implied from behavior or by means of assessment tools which may be imperfect or potentially create impediments. Since, the process of evaluating leaning is deductive itself contextual information is invaluable as it generates scenarios which can be compared and contrasted. This mapping of complex patterns can provide significant which feedback into the decision-making cycle to help newer teachers as well as improve systemic suggestions. While it may never be possible to fully map learning as a discrete activity it should be possible to cover the range of potential outcomes in a meaningful way. As this body of knowledge develops ubiquitous learning environments should become more effective as the combine limitless learning options with supports that can recognize and assist with the challenges faced by individual students.

## 10.8 Conclusion

Education as a whole has undergone huge transitions in past few years. The introduction of technology has allowed students to turn their everyday surroundings in a wealth of learning opportunities with which they can interact and evaluate for themselves. As they engage with different systems and learning objects, a wealth of information is captured providing the ability to analyze interactions in great detail and extract complex observations about learning styles, preferences, and other habits. The goal is to use this information to provide a learning environment which can be adapted to the individual student and their needs. Unfortunately this has led to a number of challenges which can be identified by the lack of supports generally seen in these environments. Automated systems have yet to fully encompass these learning environments and mechanisms for utilizing information generally require complex skills sets outside of normal professional training. In order to bridge this gap, teachers need to be supported and allowed to function effectively in ubiquitous learning environments so that they can gain operational knowledge and the ability to make decisions that can influence student learning. This suggests the need for a tool which can aggregate and display data in a friendly way that can easily be utilized and then applied to specific problems in a decision-making scenario. To do this visualization mechanisms have been proposed in a unified interface to supports the teacher even as they support students. This provides a meaningful way to address complexity in the learning process and handle problems discretely. This provides one potential solution for unlocking the full potential of ubiquitous learning environments and allowing students to follow their own learning which being fully supported and encouraged.

**Acknowledgments** Authors acknowledge the commentary and discussion with the NSERC/iCORE research group invaluable. The authors also wish to thank the support of NSERC, iCORE, Xerox, and the research related gift funding provided to the Learning Communities Project by Mr. Allan Markin. The first author would like to thank his wife Debra for her tireless efforts as an editor on every drafts and paper he has produced over the past several years.

## References

Ali, L., Hatala, M., Gaševic, D., & Jovanovic, J. (2012). A qualitative evaluation of evolution of a learning analytics tool. *Computers & Education*, 470–489.

Arnold, K. E., Tanes, Z., & King, A. S. (2010). Administrative perspectives of data-mining software signals: Promoting student success and retention. *The Journal of Academic Administration in Higher Education*, 29–39.

Friedler, S., Tan, Y., Peer, N., & Shneiderman, B. (2008). Enabling teachers to explore grade patterns to identify individual needs and promote fairer student assessment. *Computers & Education*, 1467–1485.

García-Solórzano, D., Cobo, G., & Santamaría, E. (2012). Educational monitoring tool based on faceted browsing. *LAK '12* (pp. 170–178). Vancouver: ACM.

Google Developers. (2013, May 3). Retrieved from Google Charts. https://developers.google.com/chart/.

Graf, S., Kinshuk, & Liu, T.-C. (2008). Identifying learning styles in learning management systems by using indications from students' behaviour. *Eighth IEEE International Conference on Advanced Learning Technologies (ICALT)*, (pp. 482–486). Santander.

Graph Visualization Library With jQuery—Arbor. (2013). Retrieved from jQquery Script.net. http://www.jqueryscript.net/chart-graph/Graph-Visualization-Library-With-jQuery.html. Accessed 9 Feb 2013.

Hatzilygeroudis, I., Giannoulis, C., & Koutsojannis, C. (2005). Combining expert systems and adaptive hypermedia technologies in a Web based educational system. *ICALT Fifth IEEE International Conference on Advanced Learning Technologies*, (pp. 249–253). Kaohsiung.

Hwang, G.-J., Chen, C.-Y., Tsai, P.-S., & Tsai, C.-C. (2011). An expert system for improving web-based problem-solving ability of students. *Expert Systems with Applications, 38*(7), 8664–8672.

Introduction to Using Chart Tools. (2013). Retrieved from Google Developers. https://developers.google.com/chart/interactive/docs/. Accessed 9 Feb 2013.

Lavrac, N., Bohanec, M., Pur, A., Cestnik, B., Debeljak, M., & Kobler, A. (2007). Data mining and visualization for decision support and modeling of public health-care resources. *Journal of Biomedical Informatics*, 438–447.

Li, Y. (2009). A remodeling method of automatic learning process based on LMS in e-learning. *International Conference on Web Information Systems and Mining (WISM)*, (pp. 565–569). Shanghai.

Limoanco, T., & Sison, R. (2002). Use of learner agents as student modeling system and learning companion. *Proceeding of the International Conference on Computers in Education*, (pp. 1331–1332). Auckland.

Macfadyen, L., & Dawson, S. (2010). Mining LMS data to develop an "early warning system" for educators: A proof of concept. *Computers & Education*, 588–599.

Mahendrawathi, E., Pranantha, D., & Utomo, J. (2010). Development of dashboard for hospital logistics management. *IEEE Conference on Open Systems (ICOS)*, (pp. 86–90). Kuala Lumpur.

Mitrovic, A. (2006). Large-scale deployment of three intelligent web-based database tutors. *28th International Conference on Information Technology Interfaces*, (pp. 135–140). Zagreb.

Mitrovic, A., Martin, B., & Suraweera, P. (2007). Intelligent tutors for all: The constraint-based approach. *IEEE Intelligent Systems, 22*(4), 38–45.

Oracle Corporation. (2013, Sept 28). *MySQL:* The world's most popular open source database. Retrieved from MySQL. http://www.mysql.com/.

Sachin, R., & Vijay, M. (2012). A survey and future vision of data mining in educational field. *Second International Conference on Advanced Computing & Communication Technologies (ACCT)*, (pp. 96–100). Rohtak.

The Apache Software Foundation. (2012, May 14). Retrieved from Welcome to the Apache Software Foundation. http://www.apache.org/.

The PostgreSQL Global Development Group. (2013, Sept 28). PostgreSQL: The world's most advanced open source database. Retrieved from PostgreSQL. http://www.postgresql.org/.

Wu, Q., Miao, C., & Shen, Z. (2012). A curious learning companion in virtual learning environment. *2012 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)*, (pp. 1–8). Brisbane.

Yang, G., Kinshuk, & Graf, S. (2010). A practical student model for a location-aware and context-sensitive personalized adaptive learning system. *Proceedings of the IEEE Technology for Education Conference*, (pp. 130–133). Bombay: IEEE Computer Society.

## Author Biography

**Alex Mottus** is experienced IT professional with 15 years of experience involving working with technology in both a business and educational setting. Over the years he has been involved with software development, technical support and IT management, and planning. His interest in distance learning was stoked after taking on the IT leadership of the Alberta Distance Learning Center the largest provider of 1–12 education in the province. Since that time he has worked extensively with teachers and other stakeholders to support educational technology in both a distance and classroom setting.