Exploring the design space of in-class activity visualizations

Chad Peiper, Michael Twidale, Boris Capitanu, Sam Kamin and Eric Shaffer

Abstract—Networked tablet PCs have great potential in classroom settings, including use in small group in-class problem-solving activities. It is possible to obtain substantial amounts of data about student activity during a lesson: what they referred to, notes taken and erased, bursts and lulls of activity. The raw data is necessarily very low level: time-stamped pen strokes, deletions, navigation to and from pages, to name but a few. This data has at least potential to be used in a variety of ways, one of which is enabling a teacher to monitor learning activities as they happen in real-time in the classroom. In investigating how to support this use we uncovered a particularly interesting visualization design space. The challenge is to provide the teacher with minimalist at-a-glance overview information. This information must be able to be integrated with conventional visual and auditory clues about student activity and progress that the teacher uses in order to make quick decisions about what to do next: which individuals or groups need to be addressed, how have students progressed while the instructor interacted with a group of students. The biggest constraint is that teachers want to spend the bulk of the time interacting with the students - not the system. The paper describes our first iterations of design and evaluation of use in an actual classroom setting, and the lessons learned.

Index Terms—Tablet PC, educational, learning environments, dashboard display, real-time information display.

1 INTRODUCTION

As part of a larger project investigating the potential of tablet PCs in classroom settings we are currently exploring their use in small group in-class learning activities. This kind of use builds heavily on a well established body of activity in many classrooms, both in K-12 education and at the University level in smaller discussion or laboratory section classes.

Typically these involved a series of problem tasks that might be set up on the blackboard or other public display, or selected from a textbook. However, very often a worksheet is prepared in advance by the instructor and given to the student. How might the well-understood worksheet concept be adapted for use on a tablet, and how might the technological affordances of networked tablets add value to this technique?

In investigating these questions we uncovered a fascinating design space of constraints and opportunities that require particular kinds of visualization approaches that are typically unconsidered in more conventional scientific and information visualization settings.

In Section 2 we review related work that informed our designs and also shows how our work fits into the larger picture of educational computing and visualization research. Section 3 outlines the design space. Section 4 describes our first iterations of design and evaluations of use in actual classroom settings, and the lessons learned. Section 5 outlines the new design approaches currently being developed that have been informed by that analysis. Finally section 6 shows how this work allows us to consider the design space as an evolving research space enabling the exploration of various critical research questions in this domain.

2 RELATED WORK

Considerable work has been done in the use of computers in classroom settings. See [19] for a good overview. There have also been a number of studies of tablet use. However these mostly address the learning context of a lecture and the way that tablets can support the instructor in presenting and/or the students in note taking [13, 14, 23-34]. We too have examined this setting [15, 16, 17, 18] and the work reported here builds on software developed for supporting lecture note taking. However in this paper we consider support for in-class assignments, problem solving activities and group work. These activities may take the whole of the class period, or be a small activity as a break from a traditional lecture, allowing students to practice what they have just learned.

Visualization has a long history of being used in the classroom. Although blackboard and chalk illustrations have given way to modern multimedia presentations, the idea of using visual aids to enhance student knowledge acquisition is not new. What is new is the idea of applying information technology and visualization to enhance an educator’s comprehension of how a class is learning and performing. The system described in this paper is essentially unique in addressing this task. Simoff and Maher [5] describe how data mining can be employed in aiding student assessment in collaborative learning environments. While our work has a similar goal, our approach is to employ information visualization to aid the instructor in student assessment. Wortman and Rheingans [6] use visualization to assess student progress across courses through a curriculum as opposed to the in-class assessment our system provides. Among commercial products, the DyKnow Monitor [7] and NetSupport School [8] systems both allow an instructor to see the computer screens of students and monitor their activity. However, neither of these systems tracks detailed information regarding student interaction (e.g. amount of electronic ink usage and amount of erasing) as does the system described in this paper.

Moreover, neither system presents a statistical visualization of recent student activity as we propose in this paper.

Our approach to designing a student activity visualization system has been greatly informed by Shneiderman [9] who suggests the “overview first, zoom and filter” framework we employ. The visual appearances of the student activity thumbnails in our system recall the approach of Chi et al. [10] in their work on visualization spreadsheets. Our proposed plots of student activity are visually similar to Ma’s work visualizing activity across multiple ports for cyber-security monitoring [11]. Our overall choice of a minimalist approach owes a debt to the work of Tufte [12] in general and specifically to his description of sparklines.

3 THE DESIGN SPACE OF VISUALIZATIONS TO SUPPORT TABLET PC USE

Using networked tablet PCs it is possible to obtain substantial amounts of data about student activity during a lesson, what they looked at, what they went back to, notes taken and erased, bursts of activity, lulls of inactivity, etc. The raw data is necessarily very low level, consisting of time-stamped pen strokes, deletions, moving to and between pages, copying, pasting etc. This data has at least potential to be used in a variety of ways including: formative and summative evaluation of the tablet application, and its component features, for future design iterations, and for educational research. This includes observing and comparing students’ learning at various scales of detail from short microteaching episodes of a few minutes to whole lessons and whole courses. Furthermore this data can also
be used for supporting trainee teachers by sitting along with a mentor and replaying classroom episodes to review their teaching effectiveness, enabling more skilled teachers to assess their own performance and act as reflective practitioners, and consider why certain interactions were or were not successful for different kinds of settings and students. This allows for experimentation with new techniques and fairly rapid review of initial effects, and enables teachers to monitor learning activities as they happen in real time in the classroom setting.

It is the last case that this paper concentrates on. Note that all settings may use the same raw data requiring only different kinds of processing and visualization to meet the different needs and particular time constraints of these different settings. In the case of a teacher who has assigned the students to work together in groups on a sequence of tasks, there is a classic set of choices to be made: how is the class as a whole progressing, how are the different groups progressing? Are some people racing too far ahead or lagging too far behind? Are some people and groups performing differently from what the instructor expected of their relative rate of progress? Who needs my attention right now? While I was attending to that person, what was everyone else doing?

Skilled teachers manage to constantly update their answers to these questions in real time, while dispensing advice, help, reassurance and admonishments to students. They use a host of clues including their prior knowledge of the students, their understanding of the tasks, their expectations of likely progress and likely difficulties, overhearing particular conversations and overall background conversation, body language, glancing at the worksheets from afar etc. Understandably this can be daunting for a novice teacher. It is equally daunting for a visualization developer attempting to replicate and improve upon this feat. Fortunately, this is not necessary. We do not need to replace the teacher’s external clues we need only to supplement them with additional data in a useful and usable form. That is the core of the design challenge: how to develop a visualization that a teacher can integrate into their own existing methods of managing small group learning interactions?

If such visualizations cannot be integrated easily, it is unlikely to be adopted and experimented with and gradually improved over time. If it serves as a ‘trust me’ application that requires a radical change in teaching practice, many teachers will not adopt it, and those that do will often be disappointed because it will not have gone through the thousands of rounds of iterative improvements of traditional teaching practices.

Given all the other clues that the teacher uses, and given the understandable desire to spend the bulk of the time interacting with the students, not the system, what is needed is an at-a-glance dashboard visualization that can help the teacher make quick decisions about what to do next. It does not have to be perfectly accurate in its predictions (neither are the teacher’s traditional clues), and teachers are very good at recovering from pedagogical errors. It just has to be fast, informative, and act as a useful supplement.

From this analysis, we believe that all visualizations developed need to enable the teacher to answer some (if not all) of the questions outlined above). In subsequent sections we will describe various interface features that attempt to do that and discuss our early findings about their relative success.

4 Preliminary Design and Evaluation

The most exciting prospect of deploying tablets in a classroom is the ability for us to capture and monitor the learning process, regardless of the activity and level of interaction. Our assumption is that students using tablets in the classroom are engaged in one of the following activities: taking notes, working on an exercise or assessment, or articulating, expressing, and formulating questions, doubts, or uncertainties. If a student has no interaction with the tablet, the system will not have much information on the student (other than the fact that the student has not interacted with the tablet). In this circumstance, the instructor will have to resort to the traditional means of measuring the student’s level of engagement with the lecture content.

The focus of our study is the display of student/course interactions within a class period. Aside from the technical prerequisites such as a wireless infrastructure, a whiteboard inking application and tablet pc computers (Figure 1), there were a number of preliminary design decisions and features that needed to be completed. We needed to build a system that captures, organizes, aggregates, and packages the interactions created within the student whiteboard application. The second feature was a dashboard display. Our notion of a dashboard is a separate display (not the same display the instructor teaches from) that provides information about student activity in the classroom.

Figure 1. SLICE (Student’s Learn in Collaborative Environments) Educational Technology laboratory. The room is setup in manner conducive to a collaborative learning environment.

A challenging task for most, if not all instructors, is the task of trying to gauge student interest and learning during the course of a lecture. Under current approaches, it is very difficult to understand how well the students are grasping the lecture while the lecture is in progress. It is unrealistic to require one individual to observe, assess, and evaluate (monitor) the classroom, while following a strict lesson plan and lecture objectives in an attempt to teach. The ideal situation would be to adjust the lecture midstream to help the students. Currently, teachers monitor and assess their students’ progress by a variety of mechanisms, such as observation of student participation, listening to student questions and comments, providing in-class exercises, and of course on a larger scale, graded assessments.

With the help of technology, instructors will be able to better assess and monitor their students in and outside of the classroom. Studies have shown convincingly that a teacher’s use of formative assessments is a crucial determinant of students’ learning outcomes [20, 21]. Currently, the main method of classroom assessment is limited interaction with students.

Another type of assessment is passive, or unobtrusive. This is the type of assessment that a teacher does by simply looking around the class, or by walking around the room looking at students’ individual work, body language such as facial expressions. The best teachers excel at this, but it is an uncertain undertaking, difficult to quantify, hard to learn, and applicable mainly in classrooms where the teacher knows the students very well. We believe the Tablet PC can dramatically enhance a teacher’s ability to unobtrusively [22] assess the class when students interact in the lecture with a pen and paper substituted by the Tablet PC.

4.1 Preliminary Design – Spring 2007 Pilot

Building off our experience from our earlier laptop-based system [3, 4], we developed our first Tablet PC-based system during the 2003-04 school year [2]. During the summer and fall of 2004 we developed e-Fuzion, version 2 [3], which were used for several
classes in our Tablet PC-equipped laboratory classroom. In the Fall of 2005, eFuzion, version 4, was used in the tablet classroom for a special, gender-balanced section of our freshman discrete math class (figure 6). Gender balancing was intended to help retention of women, as they are a decided minority in the large lecture section. The results were remarkable: Although the overall dropout rate for the course — across genders — was about 20%, not a single female student dropped the special section, even as the expected 20% of male students dropped it. Though still in need of closer evaluation and repetition before we can draw any scientifically-grounded conclusions, this result is highly suggestive of a real difference in educational needs between male and female students in Computer Science — and may also suggest a viable way to address those needs.

4.2 Assessment and Objectives

This pilot study work provides an example of how using Tablet PCs in the classroom can allow for fundamentally new classroom structures. In the Spring 2007 semester we taught an experimental section of our introductory programming course (CS 125) and repeated the study in the Summer for a Data Structures and Software Principles course (CS225). Of particular interest to us was to determine how the student’s performance and classroom engagement is affected by the level of their prior knowledge of the subject matter. The result showed a stark gap between students who were falling rapidly behind and those who were quickly bored.

4.2.1 Class Structure

The structure we experimented with was an attempt to deal with this situation. It is a partially self-paced class, with occasional “synchronization” points. The teacher plans the class as a sequence of objectives, each with the same structure: pre-flight (a brief question as an introduction of the topic to be taught), content presentation, self-assessments, and a post-flight (brief recap where the student need not actually solve the question but instead answer a yes or no question as to whether they believe they have the necessary knowledge to answer the question).

For the most part, the class goes through the lesson objectives together, but may move at different rates within an objective. Students completing all but the final assessment for an objective (the post-flight) are free to move on to subsequent objectives prior to the synchronous pre-flight of subsequent objectives. This structure provides a mapping of lecture objectives to student created notes while also providing a roadmap of the lecture content. This type of objective mapping provides a recordable context of the classroom session (Figure 2). For example, what the objectives are, the current status (current objective instructor is teaching) and the transition between one objective to another.

4.2.2 Preliminary Dashboard

This class also incorporates a window on the teacher’s computer — which we call the “teacher’s dashboard” — indicating how many students are at each point in the current objective. This is an illustration of how a carefully designed environment allows for the exploration of different pedagogies (Figure 3). We learned from earlier pilot studies that left to their own devices, students would get off task by running other programs instead of staying engaged in the lecture. This is why we included a current-student-status indicator (students are assumed to be either taking assessments, taking notes, or outside the scope of the whiteboard application) into our preliminary dashboard design.

This strict adherence to this classroom structure allowed an instructor to make reasonable assumptions regarding student participation. For example, students outside the scope of the application (Outside Application in the figure above) were almost always working on machine problems (programming assignments) instead of performing assessments or helping their classmates to understand the lecture material. A cursory glance at the dashboard therefore allowed the instructor to quickly determine which students were ahead, behind, and in time with the pace of the instructor. Student’s taking notes were understood to be paying attention to the instructor while student’s outside the scope of the application could be anything but on task.

Students outside the scope of the whiteboard application should have completed all assessments (pre-flight and subsequent assessments for all the objectives) and answered ‘Yes’ to the pre-flights questions. Although post-flights were performed synchronously by the class (as a means of assuring the entire class was ready to move on to the next topic/objective) if a student’s identifier was not in the last assessment list for an objective, they were considered off task. The real-time feedback produced by the above dashboard provided enough information for an instructor to pair students up for co-instruction and focus on the students requiring further explanation from the instructor. When there were no students in note taking mode, it was clear to the instructor that they could move on to the next teaching objective.

4.3 Fall 2007 Teacher’s Dashboard

In the first iteration of our Fall study we employed the use of VNC to create a display of student windows (Figure 4). The interface provided no user interaction and was a WYSIWYG display of student workspaces. The inability for the instructor to organize or search “intelligently” any of the student work spaces further motivated the need of a graphical Teacher’s Dashboard. The functional constraints and poor performance of the VNC protocol that we experienced in a class of 30 also motivated a system that could scale.
of information recorded by the pen-input devices is a collection of key to the study is the ability to record and display students’ creation (how long the user was inking) and other attributes such as stroke creation (when the stroke was first started), duration of stroke in instructor toward the students requiring special attention.

4.4.1 Data Collection

Key to the study is the ability to record and display students’ interaction with tablet (pen-input) computers. The finest granularity of information recorded by the pen-input devices is a collection of ink strokes. Each ink stroke contains pressure information, X and Y coordinate location of individual points making up the stroke, time of stroke creation (when the stroke was first started), duration of stroke creation (how long the user was inking), and other attributes such as color and id of ink stroke (Figure 5).

4.4 New Design Approaches

Having performed a number of pilot studies investigating the use of Tablet PCs we refined our study parameters accordingly. The general research goals are to design a system to display the type, level, and pace of student activity in the classroom. For example, the pace attribute might provide the instructor with information whether a student is lagging behind, moving ahead, or following closely with the lesson. How exactly the type, level, and pace are defined within differing classroom structures is one example of generality the research hopes to address. As an example, consider that the instructor might want a real-time comparison of the pace of individual students vs. an aggregate amongst a subset of students for a given activity. A cursory glance of a good dashboard might point an instructor toward the students requiring special attention.

4.4.1 Data Collection

Key to the study is the ability to record and display students’ interaction with tablet (pen-input) computers. The finest granularity of information recorded by the pen-input devices is a collection of ink strokes. Each ink stroke contains pressure information, X and Y coordinate location of individual points making up the stroke, time of stroke creation (when the stroke was first started), duration of stroke creation (how long the user was inking), and other attributes such as color and id of ink stroke (Figure 5).

4.5 Dashboard Dimensions

In our definition of the word, dashboards can vary along the following dimensions, which are discussed in more detail below: summary, selection, time interval and profile.

4.5.1 Summary Information

Summary refers to a display of either a students’ actual work, or some quantitative synopsis information. Selection refers to the number of students whose data is displayed - that is, whether the class as a whole is displayed or just a subset of the students. Time Interval refers to the period of time or frequency that the data are aggregated and or presented. Profile relates to whether the students’ prior behaviour is taken into account (i.e., whether the system maintains a historical “profile” of the class) and uses that data to modulate the dashboard display.

In addition to these dimensions, there is always the overriding issue of data visualization – given a particular choice of data points to select, there are numerous ways to present them – and of control – how the teacher may influence the dashboard display during class. We elaborate on the four dimensions listed above.

4.5.2 Actual work vs. derived data

Showing the students’ actual work means displaying the students’ desktops; thus providing the same kind of information that a teacher would get by walking around the classroom. Depending upon the selection dimension, this might involve a screen of thumbnail view of students’ desktops (which obviously would be hard to read in detail, but might still be useful), or a single screen shot (with a mechanism for switching to a different student), or a small set of larger thumbnails. The advantage of showing actual work is the detailed information it provides, but the disadvantages are that it may be too much information for the teacher to absorb in real time, and that it may be so cluttered that the teacher can, in reality, obtain no useful information.

Showing derived data means drawing graphs of physical characteristics, such as amount and speed of writing. The advantages of this approach are (1) it requires much less space per student, so we can have a more readable display of more students; (2) by using numerical data, it allows for comparisons that may be useful, such as quantities of ink during different periods of the class; (3) potentially, the computer may be able to deduce information that the teacher cannot easily infer (much less, in real time for many students); we do not yet know to what extent this may hold, but it seems a plausible possibility.

4.5.3 Entire class vs. selected students

Showing all students gives a general picture of the class, which the teacher might find useful as a way of determining whether the teaching level is appropriate: is she going too fast, leaving students behind, or going too slow, or going just about right? In effect, this allows the teacher to judge herself, using objective feedback not available in the traditional classroom. Showing individual students allows for more detail about those students; this can allow the teacher to see how those students are doing.

This is not entirely orthogonal to the other dimensions. In particular, it interacts strongly with the Summary dimension, since the number of students displayed determines the amount of detail available per student. It also strongly implicates the user interface (i.e. the teacher’s control of the display), because a display of selected students may be useful only if there is a convenient way to change the selection in real time.
4.5.4 Data aggregation period

Do we provide a picture of the class right now or over the past so many minutes? Summary information necessarily involves a non-zero length time interval. (It makes no sense to speak of, for example, “instantaneous inking volume.”) But that interval could be 30 seconds or 15 minutes. (Detail views – i.e., student desktops – would have to be refreshed constantly because they occupy too much real estate to include several snapshots.)

Advantage of a short time scale: Tells teacher what is happening now; since it contains less data, the data presented can be larger and more visible. Advantage of longer time scale: May allow teacher to see how students have reacted to various topics during a class. Over a larger time scale, the teacher might also be able to identify trends of student behavior.

4.5.5 Use of historical data for comparisons

The display may take into account the historical behavior of individual students or of the entire class. For example, a student’s inking behavior might seem normal, but would be noteworthy if that student usually is a prolific note-taker. Similarly, just as the teacher might be interested to know that students are writing differently now from fifteen minutes ago, she might like to know if they’re writing differently from how they did in the previous class or a class several weeks ago. Figure 6 illustrates the amount of time spent (in minutes) for individual pages of a midterm examination in a Computer Science Data Structures course. The graph reveals that this student spent close to 18 minutes on 2 multiple choice questions. An aggregation of time spent on page 5 across the class revealed an average of 10 minutes. This student was clearly an outlier.

Choosing a point along each of these dimensions determines what data will be shown on the dashboard. But the visualization of that information can vary in many ways, affecting the density and readability (in real-time, which is different from book-time) of the dashboard. Nor is there any reason why different regions of the dashboard might not have different data displayed. And the display may change during the class, for any number of reasons; in particular, the display may change as the class changes “mode,” e.g., shifts from ordinary note-taking to a student exercise; or, the teacher may be able to request a change, bringing user interface issues into play.

Thus, the design space is enormous. However, we want to address one question: whether a dashboard – any dashboard – can help teachers teach. Our hypothesis is that a dashboard, carefully designed, can increase the teacher’s knowledge – or, at least, her perception of her knowledge – of what the students are experiencing, and that this knowledge will be useful.

4.6 Ongoing Evaluation

The Fall 2007 version continues to be tested in a number of settings: in a first year university level Computer Science course, and in four classes at the neighboring University of Illinois Laboratory High School including courses in accelerated Spanish, Algebra 1, Algebra 2, and Geometry.

These studies involve relatively skilled teachers and motivated students, so the initial results need to be treated cautiously. We are concentrating more on identifying problems that the teachers have in using the technology and the ways that they integrate (or fail to integrate it) into their existing teaching practices. The problems in situated use, as well as the unexpected appropriations of the technology for unexpected purposes are used to inform subsequent rounds of prototyping.

5 New Design Approaches

All design involves trade-offs and the navigation of a design space. What is of interest in this case is the size and complexity of the design space and the nature of the trade-offs. As an illustration we elaborate below on a single trade-off – just one of many that we are considering.

The thumbnails are easy to understand, and extremely easy to integrate into the existing practice of teachers. They look like paper documents and teachers are already skilled at glancing at students’ paper worksheets, often from considerable distance and frequently when the paper is upside down from their perspective and yet still gaining useful impressionistic data: “Has he done anything at all? Is she just doodling? Does that look like it might possibly be a reasonable answer?”. Unfortunately even thumbnails take up considerable space, particularly when there are, say, 24 of them.

As a result we have been investigating a large-screen display option (Figure 7). In our prototype we have combined 5 monitors, 4 of which are displaying at a resolution of 1200x1600 pixels (rotated), and a 5th Wacom pen-enabled (1280x1024) display allowing the instructor to annotate and interact with a student’s whiteboard workspace.

Given the continual fall in the cost of monitors, this does not seem an infeasible setup to plan for a classroom that would also have 24 networked tablet PCs for students. However, even with this more generous than typical hardware setup, we remain pixel-constrained. Figure 8 illustrates the latest version of the visualization which is clearly designed to exploit every available pixel.
In the current version, each thumbnail is identified by a small amount of text (the student’s login ID), a number indicating which group they are in and that student’s current page (i.e., 2/4 meaning page 2 of 4). In studies of use we have found that teachers refer to the overview of thumbnails, looking at the display for just a few seconds before deciding which individual or group to attend to next. Although there are various built in options to sort the thumbnails based on derived data (such as amount of inking), these options are used rarely (Figure 9) except for the sorting by group number feature which allows the instructor to quickly glance at the work spaces of students within the same collaborative group.

The facility to zoom in on a particular thumbnail of interest is used however (Figure 10). We have taken these observations as informing subsequent design thinking where speed of interpretation and ease of integration with other information (conversation fragments, noise level, body position etc.) take priority over more detailed visualization refinement interactions by the instructor. This can be a difficult decision to make from the perspective of traditional information visualization. It is tempting to add yet more options and functionality to provide the teacher with more choices, better alternate views, charts, rankings etc. But in the real-time context of in-class activities, speed, simplicity and ease of integration into conventional pedagogy outweigh more advanced options.

In future versions we will investigate arranging the thumbnails to more closely resemble the physical classroom layout, with students working in groups around tables. With a more faithful classroom-plan layout, mapping from thumbnail to student would be much easier for the teacher, but the tradeoffs are the loss of pixels to enable such arrangement and the consequent reduction in the size of the thumbnails, making them less easy to read and interpret. We will need to study the system in use to understand if this trade-off is worthwhile, and indeed what are the hidden factors in the trade-off that can inspire future design innovation.

5.1 The larger use design space

As noted, the in-class use context creates a dauntingly large design space to explore for developing useful, usable and acceptable visualizations of state, individual, group, absolute and relative progress. But this is just a subpart of the even larger design space of the uses to which the visualizations of the captured data can be put. These include:

- Reflection by the teacher on what just happened after the class has ended
- Consideration by the teacher of sequences of classes, even of a whole semester of teaching a class
- Comparison between activity in different classes and class sections
- The teacher trying out small innovations in pedagogy around using tablet PCs and reflecting on the results

All these involve use just by the teacher herself acting as a reflective practitioner [3]. There are also uses involving others:

- Expert-teacher master classes for sharing pedagogical innovations
- Showing a class interaction at very high speed – like a speeded up action reply, with commentary explaining what
was being done and why, problems arising and how they were resolved:

- Mentoring of trainee teachers – such as going over a lesson and noting strengths and weaknesses
- Continuing professional development
- Conventional educational research into classroom activity, performing highly detailed (and typically laborious analysis) using the data obtained and visualized from Tablet use as an alternative to or as a supplement to more conventional data capture techniques such as videotapes of the class
- Detailed evaluation of tablet PC technologies, mechanisms, teaching tools and pedagogies. That is, these points in the visualization design space can serve as resources for the iterative design and testing that occurs in exploring the different pedagogical design space.

What remains to be discovered is which features of the visualization are in common to all (or most) of these and which are unique or have different relative importance. We are sure though that the underlying data is likely to remain the same. This is determined by what is possible to collect, and one might as well collect all that can be collected, given that the overheads of collection and storage are minimal. The difficulty lies in the variations in the trade-offs of different ways to process this data and how to show it. Much depends on the amount of time available to devote to analysis in each of the above contexts. This can be considered as the ratio of class time to analysis time. So for a 50 minute class, (or a 1 minute episode) how many minutes to devote to analysis? As an example, for video analysis, this ratio is can be as much as 10:1 [4].

The setting of in-class exercises is at one extreme of this continuum, where the amount of time for analysis should be minimal. Traditional educational research using video and conversation analysis is at the other extreme, with the other cases residing somewhere in between, highly dependent on context and indeed on what the technology can be designed to afford.

6 Conclusion

Tablet PCs create both an opportunity and a challenge. This applies to issues of how to use them in teaching and in the technologies developed to support this use. On aspect of this issue is the opportunity of the unprecedented amount of data that is obtainable about student’s interactions with the tablet and hence providing evidence about their learning and overall cognitive state (engaged, confused, bored, frustrated etc. This opens up immense potential for improving overall teaching effectiveness by more individualised help in a classroom context. The challenge is that this data only provides indirect evidence about students’ cognitive states. It needs to be processed and in particular it needs to be visualized and integrated with the other sources of evidence available to teachers. This paper has outlined our early work in exploring this intriguing design space through iterative prototyping and evaluation in classroom settings. Our focus has been on at-a-glance information that is easy to integrate.

We have shown how this can be done, but often at the expense of more powerful techniques and options that although of great interest to an educational researcher, just get in the way of the power of very rapid impressionistic visualization by a practicing teacher just needing small amounts of supplementary information to help them re-establish a sense of overall classroom context after interacting with an individual.

7 Acknowledgements

The authors wish to thank the Department of Computer Science at the University of Illinois and Professors Eugene Bild, Iona Boca, Jena Finch, and Craig Russell. This work was supported in part by a grant from HP and Microsoft Research.

References