Teacher Directed Active Learning Games

LORI L. SCARLATOS

TONY SCARLATOS

Stony Brook University

ABSTRACT

Games are widely recognized for their potential to enhance students' learning. Yet they are only rarely used in classrooms because they cannot be modified to meet the needs of a particular class. This paper describes a novel approach to creating educational software that addresses this problem: provide an interface specifically for teachers that enables them to define the content of the games, and track the impact on their students' learning. The games themselves use physical interfaces and multimedia to encourage collaboration and keep students active and engaged. Two specific applications are described, along with results of field-testing the applications in local elementary schools. A system for disseminating and sharing the teacher-defined content is also presented.

INTRODUCTION

Recognizing that people can have different intelligences corresponding to different ways of learning (Gardner, 1983) has led educators to call for changes in the approach to teaching (Bransford et al, 2000). These changes include providing active learning experiences that develop students' understanding and skill levels by scaffolding, building on their own prior understanding and the understanding of their classmates. At the same time, the importance of play to children's development is also being recognized (Vygotsky, 1978).

One way of providing active learning through play is with educational computer games. Gee (2003) points out that learning is a natural part of playing any game: to play a game well, one must understand the complex sign systems inherent in it. He believes that we can therefore teach more effectively by emulating the immersive qualities of games. And so, the numbers of educational games that are available have grown. In the stores, toy shelves are filled with learning games for youngsters (Buckleitner, 2008). Games for older children, developed and

tested by researchers, teach concepts in engineering, math, and science (Shaffer, 2006; Morales et al, 2006; Elliot and Bruckman, 2002). Even popular commercial games, such as the Civilization series, can be used to teach important concepts in the classroom (Squire and Barab, 2004).

Physical or tangible interfaces can make learning games even more effective, by enabling students to directly manipulate tangible representations of concepts (Ishii, 1997) and engaging physical learners (Gardner, 1983). Physical interfaces also make it possible for groups of students to work together on a problem, without having to decide who gets to control the mouse. This type of collaborative learning enables students to help one another, build on one another's knowledge, and stay focused on the problem (Marshall, 2007; Scarlatos, 2002). Tangible user interfaces have been implemented in a variety of manipulatives for learning, from Montessori-inspired manipulatives (Zuckerman et al, 2005) to math manipulatives (Scarlatos, 2006). Advances in materials science have made it possible to create an even wider range of objects that children can interact with in a game (Eisenberg, 2005). More general physical learning environments have also been developed, such as SMALLab which provides an interactive environment that enables students to discover and learn together collaboratively (Birchfield et al, 2006).

Yet even with the advent of all these games for learning, widespread use of computer games in classrooms is still elusive. A primary reason for this is that the games that are available frequently do not meet the needs of the particular curriculum, teacher, or class of students. One approach that has been taken to remedy this is to involve children in the design of the games. Druin has been in the forefront of this approach, working with students to create software and tools that enable other children to create learning experiences (1997; Guha et al, 2004). Prensky also believes that students should be involved in the creation of educational games for other students (2007). Yet even when the game designers do consult with children, educators, or education research, the resulting games are unable to adapt to specific situations and/or changing needs. One way to address this is to create tools that allow children to create their own content. For example, tools have been developed for collaboratively creating stories with tangible user interfaces (Stanton et al, 2001; Montemayor et al, 2004), and for creating computer games (Howland et al, 2007). At the MIT Media Labs, Resnick has developed digital manipulatives that allow children to explore concepts related to dynamics and systems (Resnick et al, 1998). Yet although these tools allow students to freely engage in exploratory learning, students often need their instruction to be guided by an educator who understands what needs

to be taught. Furthermore, students with different skills and knowledge often require differentiated instruction from a teacher.

Our approach is to create games that present students with problems or activities that are designed, by an instructor, specifically for the players of the game. A teacher's interface allows an instructor to define the game's content, assign it to specific players, and then later review the performance of the students in order to guide the design of subsequent game modules. Using this interface, the teacher can create different activities for different classes, and even different students within those classes. In this paper, we describe two educational applications that use teacher-defined content in this manner. Both applications employ physical interfaces to make them more engaging and game-like. We discuss the teachers' interface, emphasizing how content can vary. We then present results of initial field tests conducted at local elementary schools. Finally, we describe a system for disseminating the game and the teacher content online.

EDUCATIONAL APPLICATIONS

Two of our educational games are currently being distributed through Eastern Suffolk BOCES Model Schools program (Roces et al, 2007): SmartStep and WriteOn. SmartStep focuses on math, while WriteOn focuses on writing. Both are targeted at elementary school students. Student and teacher applications are provided for each. These applications were developed using Macromedia Director, a multimedia authoring environment that facilitates rapid prototyping and development. The completed applications are distributed as executables for both Windows and Macintosh platforms.

SmartStep

As shown in our standardized tests, only 39% of American fourth graders are at or above the Proficient level in math (Lee et al, 2007a). One of the best ways to gain proficiency with numbers and operations is with practice (Gersten et al, 2008). Furthermore, it is best when this practice is individualized, so that students only drill what is needed (Van de Walle, 2001).

SmartStep reinforces basic math skills by having K-5 students solve math equations, using a DDR (Dance Dance Revolution) dance pad for input. As in hopscotch or jump rope, the physical activity helps to keep students engaged while honing motor skills, pattern recognition, rhythm and coordination. Although SmartStep was designed to be used by one student at a time, we have found that small groups of students, gathered around the dance pad, can effectively

collaborate in the activity. Even when a single student is using SmartStep in the classroom, we have observed fellow students shouting encouragement and offering help.

The content of a SmartStep game is determined by a playlist, which points to one or more math activities. Each math activity, in turn, is defined by one or more equations, which are stored as strings. An equation can contain both literals and variables, and is interpreted using standard precedence ordering. A variable may be either a random number (with the range specified), a number from a sequence (with the first number, increment, and size of the set specified), or a number selected from a set (with all of the values in the set explicitly specified). Parameters within the activity determine an ordering for the equations, how many problems will be presented (using the equations to generate them), and how much time will be allowed to solve each problem. This content structure allows for a great deal of flexibility, while maintaining a small record size.

Student Game

The student application uses a colorful animated interface to guide students and provide feedback. All interaction with this application is conducted with the dance pad. Students start their SmartStep sessions by signing in with a user name or code assigned by the instructor. This determines which learning activity will be used. If the student does not enter a user name, a default activity is used.

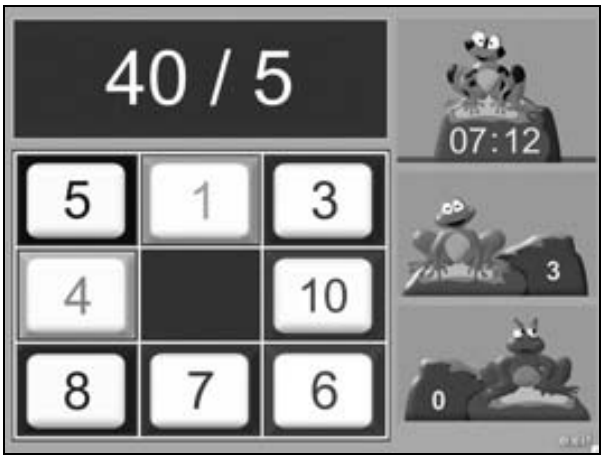


Figure 1. SmartStep game interface

Figure 2. SmartStep game summary screen

The game interface (figure 1) shows an equation at the top of the screen and a set of possible answers below. Each of the possible answers corresponds to a space on the dance pad. The empty central space represents the neutral place where the student stands.

Three animated frogs on the right side of the screen show how the student is doing. The top frog sits on a rock that shows the remaining time, while the water rises behind him (to show time passing). The middle frog shows the number of accumulated points. The bottom frog shows how many wrong answers have been given. When a student steps on the correct answer, a check appears over the corresponding square; points are accumulated; the middle frog wags his head happily; and the next problem appears. When a student steps on an incorrect answer, an 'X' appears over the corresponding square; the number of wrong answers increases while the bottom frog smiles gleefully; and the problem remains on the screen. After answering incorrectly three times, a translucent footprint appears over the correct answer.

The game ends either when the student has answered all of the questions, or when the game times out. A final screen shows how the student did (figure 2). If the student has accumulated more points than wrong answers, and the game did not time out, then the student "wins". Data reflecting how the student did is saved in a time-stamped record in the database.

Teacher Application

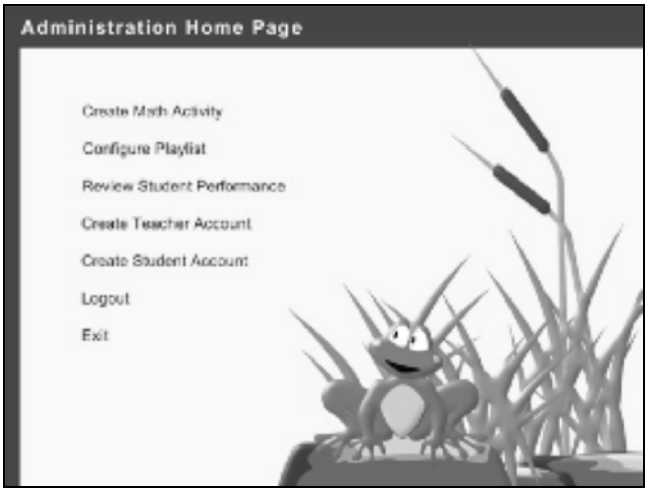


Figure 3. SmartStep teacher's main menu

The teacher application allows teachers to define activities, assign activities to groups of students, and maintain a database of their own students. Figure 3 shows all of the options available to the instructor. Unlike the student application, all interaction for this application is conducted with a mouse and keyboard.

A teacher using the system is given a default account and password, which provides access to the rest of the system. New accounts may be created for additional teachers; or a single teacher

may generate multiple accounts representing different classes that he or she is teaching. Student accounts are created in association with a particular teacher account, which enables the teacher to define activities for the students and review their performance.

The teacher labels a new math activity with a name, and then uses the menu-based interface to define a set of equations for the students to solve. An equation can use any combination of addition, subtraction, multiplication, and division, using both variables and constant values. Parentheses may also be used to show precedence. The teacher can use default settings for the variables, or change those settings to define different ranges, sequences, and sets. The use of variables and "shuffling" ensures that students will see a different set of problems each time they play. An activity can also include more than one equation, and have those shuffled as well. For example, students can learn that multiplication is commutative by solving "R1 x 3" and "3 x R1" in a "three times" activity. Finally, the instructor also specifies how many problems to generate for each game, and how much time to allot for each problem.

The teacher creates a playlist by selecting one or more pre-defined math activities from a menu. A playlist is then assigned to one or more students in the teacher's class. It is this assignment that determines what problems will be presented to a particular student when he or she signs in on the student application.

WriteOn

Among American children in the fourth grade, only 31% can read at the proficient or advanced levels (Lee et al, 2007b). Phonemic awareness (the ability to hear and identify sounds in spoken word), and phonics (the relationship between written letter and spoken sounds), have been pinpointed as two of the most crucial areas of instructional focus. For this reason, spelling lessons have become of major interest to grade school educators. WriteOn is a multimedia solution to this national crisis.

WriteOn gives children the opportunity to practice both their spelling and their handwriting. Students are prompted by an audio cue to spell a word, which they can write on a graphics tablet or type on a keyboard. They can also write on an interactive whiteboard or touch screen, facilitating classroom collaboration.

A WriteOn lesson is stored as a list of spelling words. Each word in the list corresponds to an audio file, which has the teacher saying the word and putting it into context.

Student Application

Students using WriteOn must first sign in, so that their performance can be recorded in the database. If the student enters a username not found in the database, a new entry is made for that student. The student is then given a selection of lessons (i.e. spelling tests) to choose from.

In the lesson (figure 4), students are prompted by a pre-recorded voice to spell a particular word. They then write the word (to the best of their ability) on a writing tablet, or type it on the keyboard, and click a Submit button. If the spelling is correct, they receive auditory encouragement and then see the next word in the list. If the spelling is incorrect, any letter that they get correct will appear on the screen, while those that are in incorrect remain hidden with an underscore. The student has the ability to try wrong words until they get it right or skip a word if they find it too difficult. Skipped words, missed words, and an overall score are stored in a time-stamped record in the database at the conclusion of each lesson.

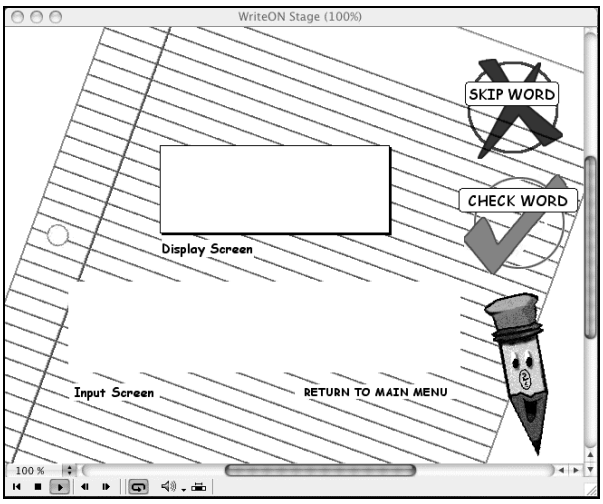


Figure 4. WriteOn student activity interface

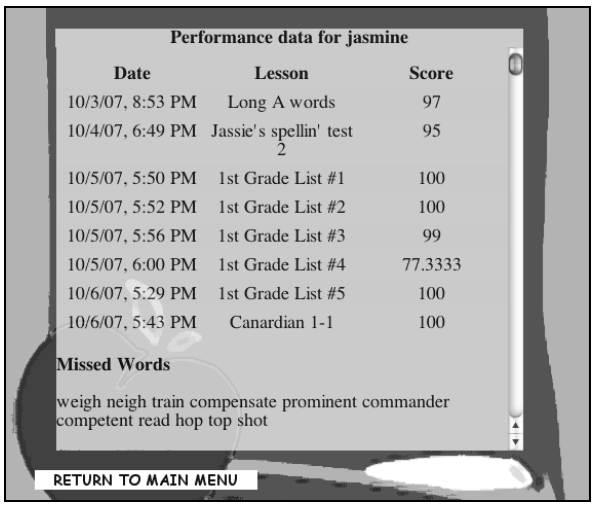


Figure 5. WriteOn student performance shown in the teacher interface

Teacher Application

We initially created WriteOn with fifteen pre-made lessons, containing spelling lists for first graders developed by a master teacher. Each of these lessons focuses on a particular sound or phoneme. Because of the importance of phonemic awareness to this activity, and because synthetic voices can be difficult to understand, we recorded each of these words individually. However, we soon recognized that other schools might have other spelling lists, and individual teachers might want to add words relating to other topics being taught in the classroom. We

therefore added an option to the administrative interface enabling teachers to record their own lessons.

After a descriptive name is given to the new lesson, the application jumps to a recording interface. The teacher types each word in a text field, and records his or her voice prompting the student. The teacher can begin this prompt with instruction ("Spell the word …"), give an example of the word used in context, or simply say the word to be spelled. The interface provides an option for reviewing the recording before saving it in the list.

The teacher application also allows instructors to see how their students are doing (figure 5). The student records show which words the student is having trouble with, and also shows improvement over time.

FIELD TEST RESULTS

SmartStep and WriteOn have both been distributed through the Model Schools program of the local Board of Cooperative Educational Services (BOCES). BOCES provides technology coordinators to member schools, who help to install and use instructional technology in the classroom. We conducted two separate training sessions for these technology coordinators. Altogether, we distributed 30 copies of the software and loaned out 23 dance pads and 6 graphics tablets, to be used in more than 30 schools across the area.

Figure 6. Using SmartStep in the classroom

Most of the feedback that we received was regarding the use of SmartStep. We found that SmartStep is generally used one of two ways: either as a group learning activity during special sessions, or as an individual practice session in a corner of the classroom. In the first case, the technology coordinators have separate classrooms that groups of students are brought into. The SmartStep interface is projected on a screen in the front of the room, with the dance pad placed in front of it. The teacher will also generally play some upbeat music to set the mood. Students in this case will take turns solving problems, receiving encouragement from their classmates. Teachers

working in this mode have found that the encouragement that the players get helps to bolster confidence in their ability to "do the math", which translates into improved math skills over time.

In the second case, students who finish their in-class assignments early are "allowed" to play with SmartStep. Teachers have found that, in addition to improving students' math skills, this motivates students to do their other work quickly, so that they get a turn using the game.

"The program is a wonderful re-teaching tool for mathematical concepts that need to be instilled in children at a young age. We are able to use the program in the morning to review multiplication facts that have been covered previously. We also use it to monitor our progress with speed and accuracy. The system is a great multisensory teaching tool that we get excited to use."
"The students love it. It is a real treat. It is great as a review of basic math facts and it gets them out of their seats for a time. I think the movement in conjunction with the math will help them to remember the math facts. It is helpful to me as a motivational tool. 'If you are working on your current assignment you may be picked to use the smart step.' The kids all want to be picked. I really like too."
"We have been using the Smart Step program and have had all positive feedback. I can't wait for the updates because this is the best program that I have seen for having fun while you learn. I have had requests for having a dance pad in each classroom so that they can use it as a center."

Table 1. Teacher testimonials.

The response to SmartStep has been overwhelmingly positive. Table 1 shows sample teacher testimonials. In addition, teachers have told us that they like being able to adjust the content to make it fit the current needs of their students. They also like being able to review student performance.

Hello my name is Kristine. I am in 4th grade and I love the program. When I go to school I'm looking at smart step just waiting to do it. Your program is awesome. The good things about Smart Step are it's very, very fun and I like how you kind of dance and I like what it is called.
My name is Sally. I'm in third grade. I really like Smart Step. The good things I like are that you're timed and it helps with your multiplication. I also like that there is a pad and frogs.
My name is Erik. I'm also in 4th grade. Smart Step is good for me because it helps me get better and better at math. Smart Step is fun too. Thank you for letting us use Smart Step.

Table 2. Student testimonials.

Table 2 shows sample student testimonials. The only complaint that we received from them was regarding the summary screen at the end. If the player runs out of time, the "timer frog" is shown to be crying. Children generally think this is too sad. We plan to fix this in a subsequent version.

Although WriteOn has had much less use, it has also proven to be a useful means of practicing skills already learned in the classroom. One surprising result is that, as we have discovered, learning can be further enhanced by having the students use the teacher application. For example, when a student is first given a spelling list, he or she is asked to create a WriteOn spelling lesson. The student subsequently gets practice writing the words, saying the words, and thinking of how to use those words in sentences. Students can then quiz themselves, using either their own lessons or lessons created by their classmates.

CONTENT DISTRIBUTION

Although teachers appreciate the ability to fine-tune the educational activities, teachers have little time to do much development. We have therefore devised a strategy for sharing the content over the Internet. Figure 7 shows the architecture for this system.

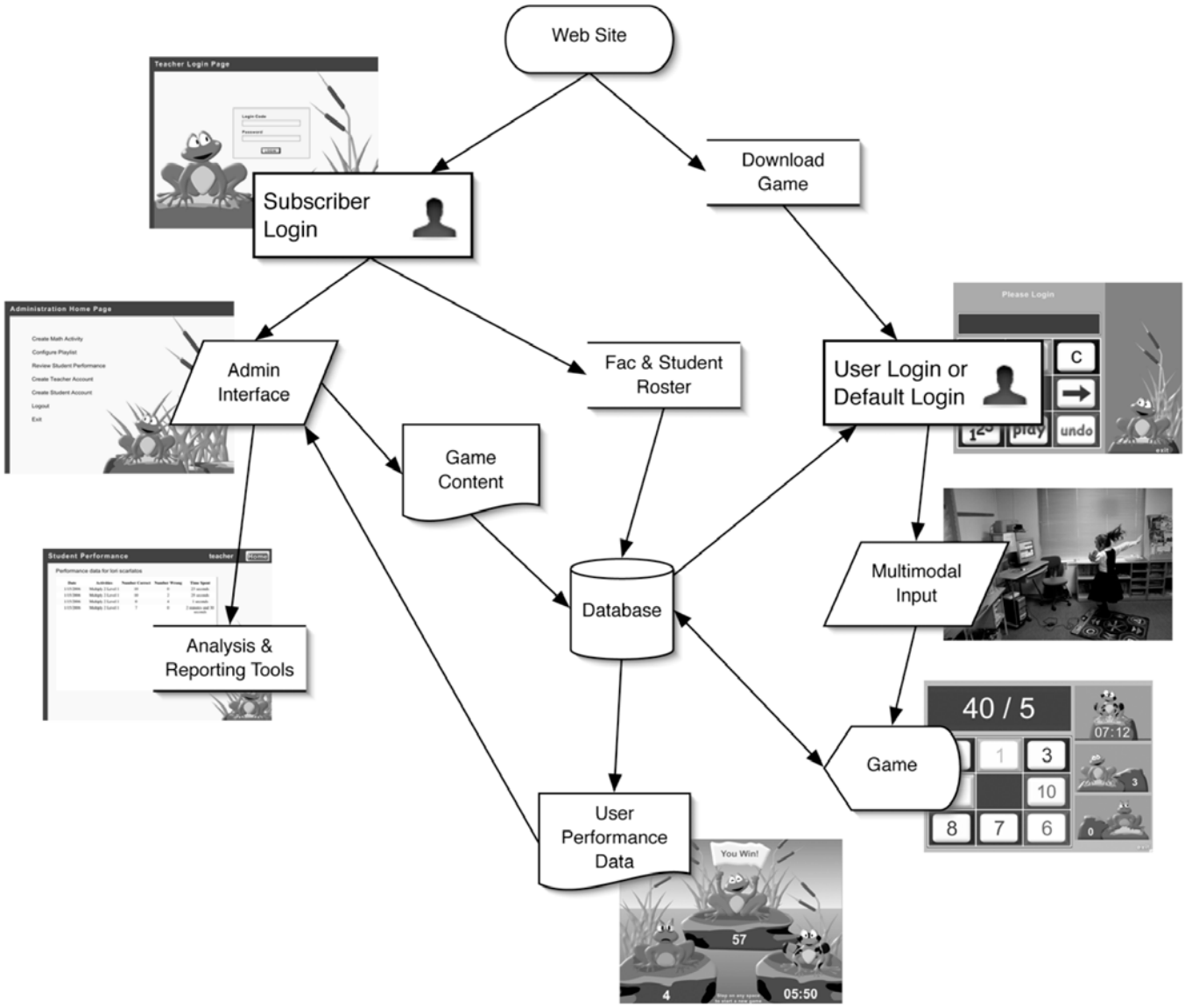


Figure 7. Architecture for the educational game sharing system.

In this system, a central website serves as a distribution center for the games. Here, students and teachers can download complete applications, updates, and user manuals. The website also serves as a center of the community using the game.

The student applications (games) can be downloaded by anyone. This way, students can use these games at home or at school. Although the games use physical interfaces in the preferred mode, traditional input devices (keyboard and mouse) can be used instead if the student does not have access

to those physical interface devices. All of the games come with a default set of content representing standards within the curriculum.

Teachers must register with the system, using either a school or personal code, in order to use it. Using a password-protected account, the teacher can create accounts for his or her students, and assign them to groups for the purpose of distributing content. Content modules can be selected directly from a shared set, selected and then modified slightly, or created new by the teacher. Any new or modified lessons that the teacher makes are tagged with the teacher's account ID. Although the content is not visible to others by default, the teacher can choose to share lessons with others.

Once a student has an account on the system, he or she can sign in before playing the game. This ensures that the game will use the appropriate content for that student, and that the student's performance will be saved in the central database. Later on, the teacher can see which students have used the game, how many times they used it, and how well they did. The teacher can also view a class summary using a variety of views (e.g. average score, words or problems most commonly missed, etc.). School administrators can see summaries of all the classes in their school, but cannot view information about individual students.

CONCLUSIONS

Both SmartStep and WriteOn have been proven as useful learning tools in the classroom. As we have shown, they may also be used in the home or assigned as homework, with students using these applications to practice what they learned in school.

Key to the success of these programs is the ability to modify the content so that it fits the current needs of the curriculum, classroom, and individual students. We have presented a system for archiving activities designed by the teachers, distributing games and content to the students, and gathering evaluative data reflecting student performance. Our hope is that, with this system in place, teachers will find it easier to take advantage of the benefits offered by computer-based games and activities.

ACKNOWLEDGMENTS

We wish to thank the students who worked on SmartStep and WriteOn, and the students and teachers who tested these applications. We also wish to thank Darlene Roces of Eastern Suffolk BOCES, who has been a valuable collaborator on this project. This work has been supported, in part, by National Science Foundation grant number EIA-0203333.

REFERENCES

Birchfield, D., Ciufo, T. and Minyard, G. SMALLab: a mediated platform for education. *SIGGRAPH '06 Educator's Program* (Boston, MA, August 2006), article no. 33.

Bransford, J. D., Brown, A. L., and Cocking, R. R. (eds.). *How People Learn: Brain, Mind, Experience, and School*. National Research Council, National Academy Press, 2000.

Buckleitner, W. The State of Children's Interactive Media, *Exchange*, January/February 2008, 62-66.

Crystal, A. Design research for a context-aware capture system to support biology education. *DIS 2006* (University Park, PA, June 2006), 352-353.

Druin, A., Stewart, J., Proft, D., Bederson, B. and Hollan, J. KidPad: a design collaboration between children, technologists, and educators. *CHI '97* (Atlanta, GA, 1997) 463-470.

Eisenberg, M. The Material Side of Educational Technology. *Communications of the ACM*, vol. 48, no. 1 (January 2005), 51-54.

Elliott, J. and Bruckman, A. Design of a 3D interactive math learning environment. *Symposium on Designing Interactive Systems* (London, UK, June 2002), 64-74.

Federation of American Scientists. *Summit on Educational Games - Full Report*, 2006. Available at http://www.fas.org/gamesummit/.

Gardner, H. *Frames of Mind: The Theory of Multiple Intelligences,* Basic Books, 1983.

Gee, J.P. *What Video Games Have to Teach Us About Learning and Literacy*, Palgrave Macmillan, New York, NY 2003.

Gersten, R., Ferrini-Mundy, J., Benbow, C., Clements, D.H., Loveless, T., Williams, V., Arispe, I. and Banfield, M. *Foundations for Success: Report of the Task Group on Instructional Practices* (Draft Report), National Mathematics Advisory Panel, U.S. Department of Education, March 2008.

Guha, M.L., Druin, A., Chipman, G., Fails, J.A., Simms, S. and Farber, A. Mixing ideas: a new technique for working with young children as design partners. *IDC '04* (Maryland, June 2004), 35-42.

Howland, K. Good, J. and Robertson, J. A learner-centered design approach to developing a visual language for interactive storytelling. *IDC '07* (Aalborg, Denmark, June 2007), 45-52.

Ishii, H. and Ullmer, B. Tangible Bits: Towards Seamless Interfaces Between People, Bits and Atoms, *Proceedings of the SIGCHI conference on Human factors in computing systems* (Atlanta, GA, 1997) 234-241.

Lee, J., Grigg, W. and Dion, G. *The Nation's Report Card: Mathematics 2007*, National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, NCES 2007-494.

Lee, J., Grigg, W. and Donahue, P. *The Nation's Report Card: Reading 2007*, National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, NCES 2007-496.

Marshall, P. Do tangible interfaces enhance learning? *Proceedings of TEI '07*, February 2007, 163-170.

Montemayor, J., Druin, Al, Chipman, G., Farber, A. and Guha, M.L. Tools for children to create physical interactive storyrooms, *ACM Computers in Entertainment*, 2(1), January 2004, article 3.

Morales, C., Martinez-Hernandez, K., Weaver, G., Pedela, R., Maicher, K., Elkin, E., Danforth, D. and Nattam, N. Immersive chemistry video game. *SIGGRAPH '06 Educator's Program* (Boston, MA, August 2006), article no. 50.

Prensky, M. *Students as Designers and Creators of Educational Computer Games: Who Else?* 2007. Available at http://www.marcprensky.com/writing/Prensky-Students_as_Game_Creators-.pdf.

Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K. and Silverman, B. Digital manipulatives: new toys to think with. *CHI '98* (Los Angeles, CA, April 1998) 281-287.

Roces, D., Scarlatos, T. and Scarlatos, L. Creating Powerful Connections: Eastern Suffolk BOCES and Stony Brook University, presented at the 2nd Annual *Celebration of Teaching and Learning*, New York, NY, March 2007.

Scarlatos, L. Tangible Math. *International Journal of Interactive Technology and Smart Education*, vol. 3, no. 4 (November 2006), 293-309.

Scarlatos, L.L. An Application of Tangible Interfaces in Collaborative Learning Environments, *SIGGRAPH 2002 Conference Abstracts and Applications*, July 2002, 125-126.

Shaffer, D.W. *How Computer Games Help Children Learn*, Palgrave Macmillan, New York NY, 2006.

Squire, K. and Barab, S. Replaying History: Engaging Urban Underserved Students in Learning World History Through Computer Simulation Games. *Proceedings of the 6th international conference on Learning Sciences* (Santa Monica, CA, June 2004), 505-512.

Stanton, D., Vayon, V., Neale, H., Ghali, A., Benford, S., Cobb, S., Ingram, R., O'Malley, C., Wilson, J. and Pridmore, T. Classroom collaboration in the design of tangible interfaces for storytelling. *CHI '01* (Seattle, WA, 2001), 482-489.

Van de Walle, J.A. *Elementary and Middle School Mathematics: Teaching Developmentally*, 4th Edition, Addison Wesley Longman, 2001.

Vygotsky, L.S. *Mind in Society: The Development of Higher Psychological Processes*, Cole, M., John-Steiner, V., Scribner, S. and Souberman, E. eds., Harvard University Press, 1978.

Zuckerman, O., Arida, S. and Resnick, M. Extending tangible interfaces for education: digital montessori-inspired manipulatives. *CHI '05* (Portland, OR, April 2005), 859-868.

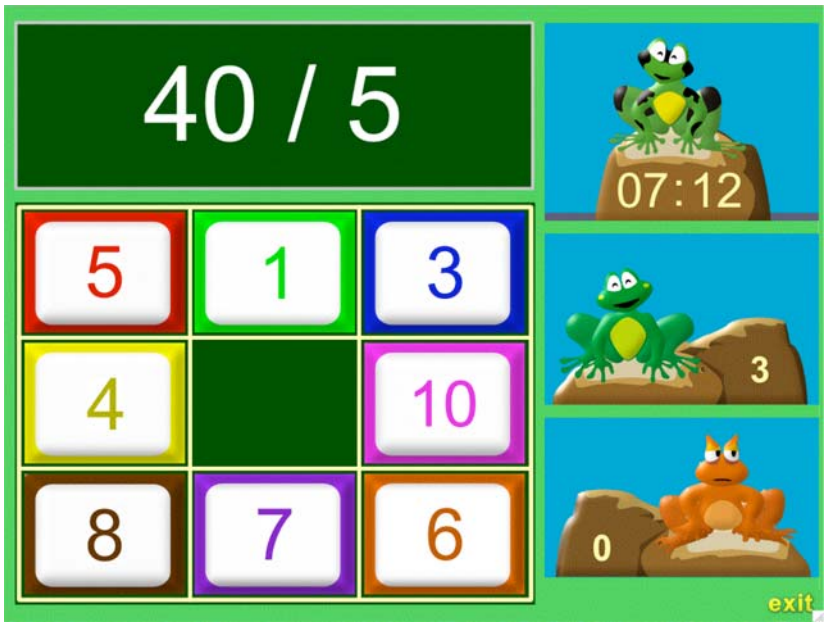


Figure 1.

Figure 2.

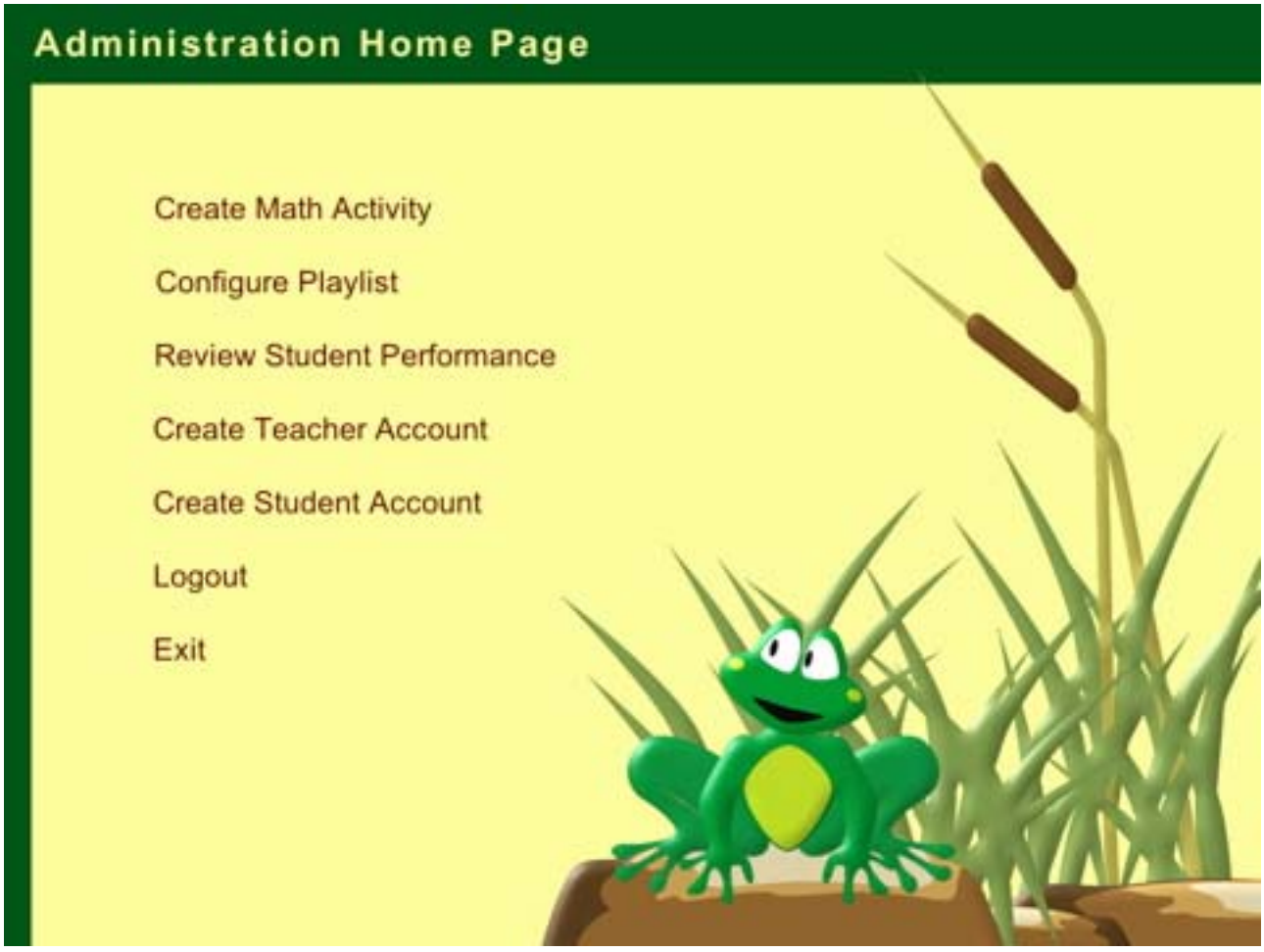
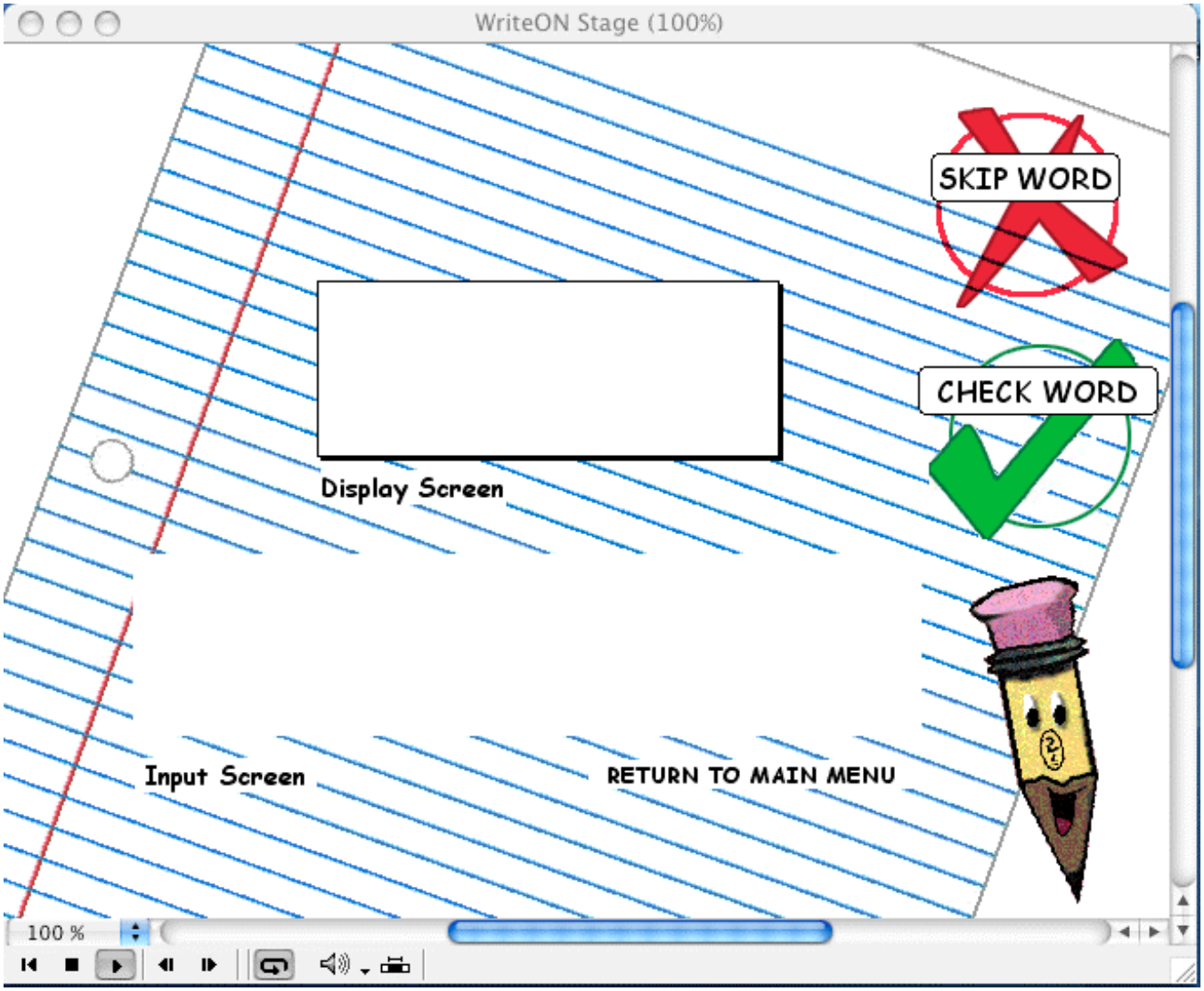

Administration Home Page
Create Math Activity
Configure Playlist
Review Student Performance
Create Teacher Account
Create Student Account
Logout
Exit

Figure 3.


WriteON Stage (100%)
SKIP WORD
CHECK WORD
Display Screen
Input Screen
RETURN TO MAIN MENU
100 %
Figure 4.

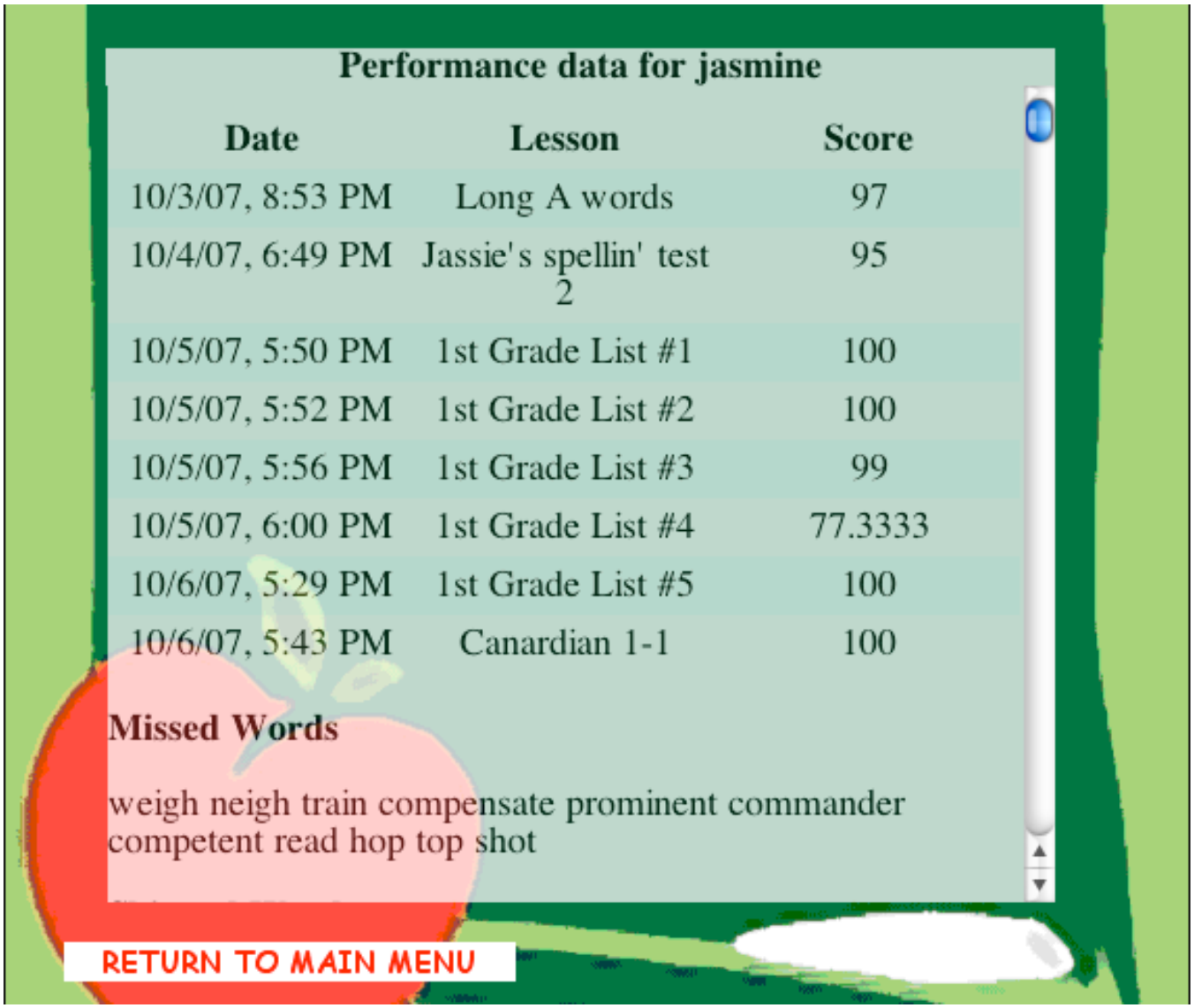

Performance data for jasmine
Date
Lesson
Score
10/3/07, 8:53 PM
Long A words
97
10/4/07, 6:49 PM
Jassie's spellin' test 2
95
10/5/07, 5:50 PM
1st Grade List #1
100
10/5/07, 5:52 PM
1st Grade List #2
100
10/5/07, 5:56 PM
1st Grade List #3
99
10/5/07, 6:00 PM
1st Grade List #4
77.3333
10/6/07, 5:29 PM
1st Grade List #5
100
10/6/07, 5:43 PM
Canardian 1-1
100
Missed Words
weigh neigh train compensate prominent commander competent read hop top shot
RETURN TO MAIN MENU

Figure 5.

Figure 6.

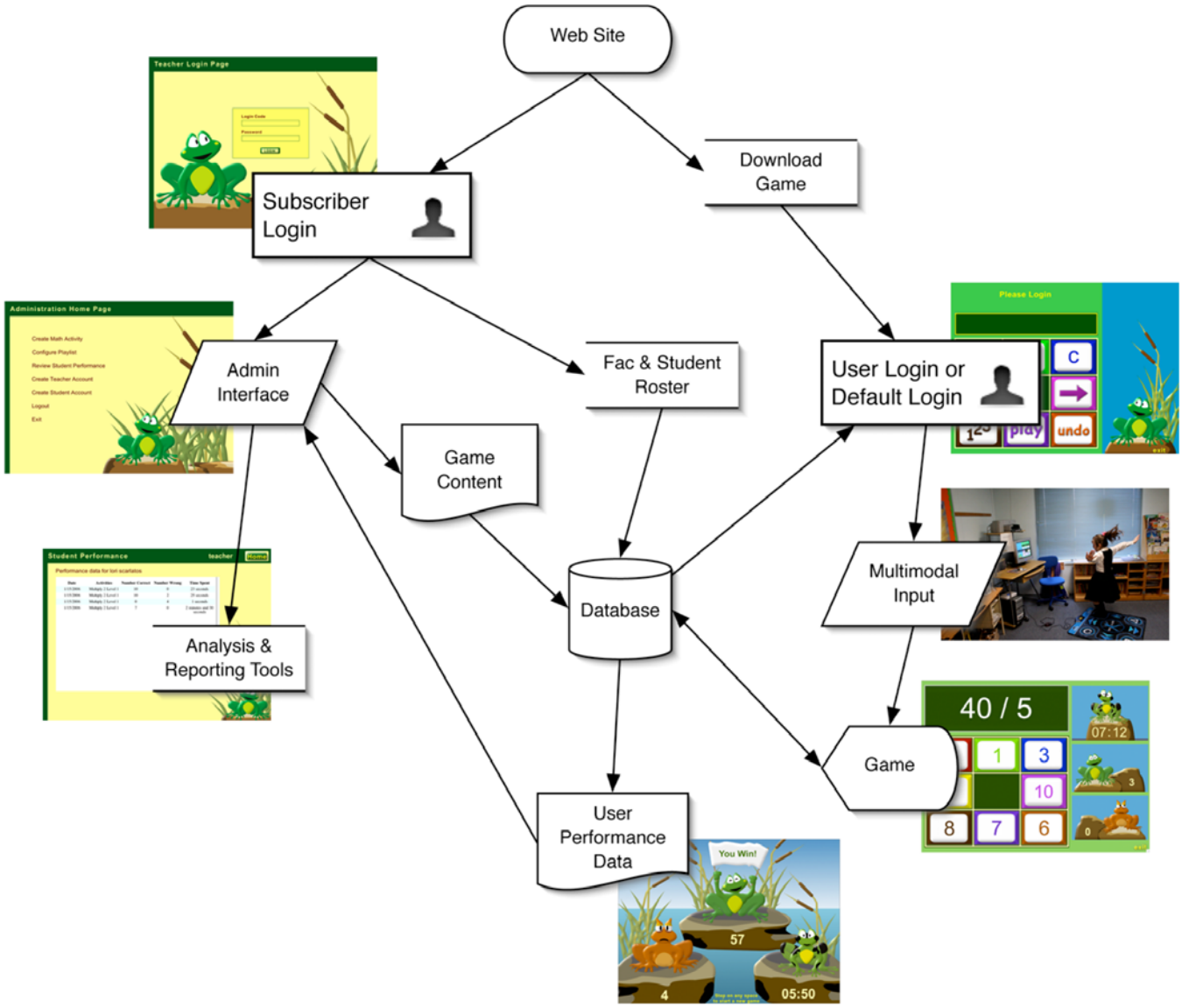

Web Site
Teacher Login Page
Subscriber Login
Download Game
Administration Home Page
Admin Interface
Fac & Student Roster
User Login or Default Login
Please Login
Game Content
Student Performance
Analysis & Reporting Tools
Database
Multimodal Input
40 / 5
Game
User Performance Data
You Win!
57
4
05:50

Figure 7.