EduBingo: Developing a Content Sample for the One-to-One Classroom by the Content-First Design Approach

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Abstract
The successful adoption of technologies in classrooms, we argue, relies on a greater emphasis on content-related pedagogical models for technology enhanced learning design. We propose the *content-first design,* an approach to creating content sample in the one-to-one classroom—classrooms with a wireless enabled computing device available for each student. To demonstrate this design approach, we take arithmetic calculation (fractions, multiplications, divisions, etc.) in elementary schools as the subject domain with EduBingo, an educational game system played in one-to-one classrooms. The system allows the teacher to monitor the accuracy and speed of the student answers during a game session, and the students can reflect on their answers after the game. Two trial tests are described, one focusing on the students while the other on the teacher. The first test indicates that the students make progress on arithmetic fluency from one session to another and that the game promotes positive affect; the second illustrates how a teacher felt the game fit into her classroom practices. This paper emphasizes those considerations that are most vital to the content-first design approach proposed herein.

Keywords
Content-first design, Technology enhanced learning, One-to-one classroom, Bingo game, Procedural fluency

Motivation

More than twenty years ago, one of the authors of this paper used a Lisp machine, which cost fifty-thousand US dollars, to implement an intelligent tutoring system prototype for his doctorial research. After a trial test by his two friends, he wrote and published a few papers, then graduated. But such computers were far too costly for any real world practice in the 80's. Furthermore, new models emerged every two years—computers evolved rapidly at that time—and hardly any portion of the system implemented could be reused. Except for a legacy of ideas, in the form of published papers, nothing was left. This was a typical scenario of *dream-based research*, in which researchers explore potential opportunities that innovative technology might someday provide to reform education in the future—often a distant future. This story provides an early glimpse at some of the difficulties involved in efforts to transfer results from research in the field of technology enhanced learning.

Today, innovative technologies continue to breathe new life into dream-based research. A large number of researchers in the field are still delving into it. On the other hand, more and more people can afford to own powerful computing devices for their personal use, bringing the advent of the one-to-one (1:1) classroom: classrooms where every student uses at least one wirelessly connected computing device (Norris & Soloway, 2002, 2004). This, for the first time in history and despite all sorts of technological and societal challenges, gives rise to the *adoption-based research*—research that works towards the adoption of technology enhanced learning in real world educational settings, both formal and informal (Chan *et al.*, 2006; Liu *et al.*, 2003; Roschelle, Penuel, & Abrahamson, 2004; Zurita & Nussbaum, 2004).

Compared to other social sectors, such as commerce, industry, civil services, entertainment, and others, education, especially schools, is perhaps the slowest sector to enter the digital era. Furthering this pessimistic view was a study mandated by the United States Congress on a large scale evaluation of educational software—15 reading and mathematics products used by 9,424 students in 132 schools during the 2004-2005 school year (Paley, 2007). The study, as measured by their scores on standardized tests, compared students who received the aid of technology with those who did not. No statistical difference was found. Some researchers have speculated that these commercial products might not be fully exploiting the real power of digital technology for learning. However, Halverson and Collins (2006) argued, despite the catalytic power of information technology, schools, being social institutes, may leave their core practice untouched. Nevertheless, researchers have reported positive successes (Abowd, 1999; Anderson *et al.*, 2003; Dufresne *et al.*, 1996; Gay *et al.*, 2001; Huang, Liang, & Wang, 2001; Liu *et al.*, 2003). Additionally, many researchers believe that, as shown in the first debate on the Internet organized by the magazine Economist (Cottrell, 2007), the new medium of digital technology will ultimately bring about a completely different form of schooling.

Adoption is hard, so is adoption-based research. By any significant measure, the research community has not started adoption-based research yet. Although many exciting programs and advances have been proposed, the progress resulting from decades of funded studies has not resulted in “pervasive, accepted, sustainable, large-scale improvements in actual classroom practice, in a critical mass of effective models for educational improvement" (Sabelli & Dede, 2001). The majority of our research is still being conducted in laboratories where we design systems either for online collaborative learning or for individual learning or tutoring. Researchers, not the school, leave the classroom, the place where formal education mostly takes place, untouched by information technology. In reality, only a few researchers have entered classrooms, taking a classroom as a research unit for design and investigation, establishing research examples of the adoption of technology in classrooms. Nevertheless—with the emergence of 1:1 classroom technology, with the call from society for adopting technology in education, with the calls from the funding agencies, the wheels of doing adoption-based research are starting to turn.

In this paper, we argue that adoption-based research demands a change in the emphasis of research, not the technology first, not the experiment first, but the *content* first—taking content design, grounded in theories, in 1:1 classroom settings as the first priority, and leaving technological implementation, experiment, and refinement for later. In particular, we introduce the content-first design approach to 1:1 classroom research, emphasizing four design concerns: content sample identification, learning assessment goal, learning flow, and teacher adoption. We describe the rationales of these concerns and exemplify them by detailing the design of EduBingo for the 1:1 classroom. Subsequently, we describe two trial tests of EduBingo, and, finally, give our concluding remarks.

Content-First Design and Content Sample

The term “content” in this study broadly refers to pre-designed learning activities associated with materials, that is, *content = material + pre-designed activity*. The broadness of this definition intends to emphasize that content is not simply codified knowledge (material) such as static web-pages. Both the material and the learning activity (pre-designed activity) should be considered in conjunction, providing the means of how the material is used in the activity. For example, reading a book is a content, in which the articles in the book are the material, and the activity reading is the pre-designed learning activity. Thus, materials are information or semiotics embodied in the paper medium, which compose the book, and the pre-designed activity is the reading of the book by a reader. In the foreseeable future, classrooms will continue to rely on textbooks. How to transcend the current classroom’s practice that mainly uses textbooks to the 1:1 classroom practice that mainly uses learners’ devices is the key issue.

A variety of issues are inherent in attempts to shift to a 1:1 classroom practice. In the real world practice, teachers, however, mainly care about the subject matter—their teaching of the subject matter and the coverage of the subject matter—more than anything else. Effective teaching models must be subject domain dependent. This is indeed the essential concept of pedagogical content knowledge (PCK), the knowledge of teaching which lies at the intersection of subject domain and pedagogy (Shulman, 1986). It includes “an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction” (Shulman, 1987, p.8). Thus, it reflects the capacity to transform the domain knowledge into forms that are pedagogically powerful and yet adaptive to the students.

Four interdependent concerns are primary to content-first design—content sample identification, learning assessment goal, learning flow, and teacher adoption—each of which relates PCK to some extent. We chose elementary arithmetic calculations as our content sample. In the following sub-sections, we discuss these four concerns alongside the content sample.

First concern: Content sample identification

Given that there are no essential differences between the 1:1 curriculum and a traditional curriculum, we begin by selecting a portion of the traditional curriculum that is to be transformed into the 1:1 content sample. Usually a curriculum can be decomposed into different parts; a content sample may then be developed for each part. However, consideration of the relation of a content sample in a complete 1:1 curriculum is useful; once content samples across the curriculum have been established, they are assembled and expanded to form a complete 1:1 curriculum. In the process of developing a complete 1:1 curriculum, the curriculum is scaled up in collaboration with teachers.

Arithmetic calculations as a content sample

To exemplify the content-first design in a 1:1 classroom, we take the arithmetic calculations—addition, subtraction, multiplication, and division—as a content sample. This content sample is an essential topic in the mathematics curriculum from the first-grade to the fifth-grade. Success in one subtopic in arithmetic calculations could be built upon to extend to related subtopics and to the mathematics curriculum in other grades.

Second concern: Learning assessment goal

If content sample identification talks about what to learn, then learning assessment goal speaks of how well to learn. As Shulman (1987) has shown, PCK research reveals that we should distinguish what to learn from how to learn it. Additionally, there is often another specific concern—how well to learn. Emphasizing that this is measured by individual progress towards meeting assessment goal, this concern directly affects pedagogical design. Only by targeting the assessment goal in the design, can we know what material is needed and what pre-designed activity is appropriate for the content sample. Striving to fulfill the assessment goal, a content sample should be designed and re-deigned, experimented and re-experimented in order to seek continual improvement.

Fluency as an assessment goal

In the elementary mathematics, education researchers expect students to acquire a set of capabilities: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (National Research Council, 2001). Concepts, procedures, problem solving strategies, and reasoning are what to learn; whereas understanding, fluency, competence, adaptability, and productive disposition are how well to learn, which, in turn, give us a set of assessment goals. Some mathematics educators and researchers define procedural fluency as "*skill in carrying out procedures flexibly, accurately, efficiently, and appropriately*" (National Research Council, 2001, p.116). In this study, fluency, our assessment goal, is limited in arithmetic accuracy, which is the ratio of correctly answered problems to all answered problems, and efficiency, which is the average time of answering a problem.

Third concern: Learning flow

Learning flow concerns how to learn, aiming at engaging students in a pre-designed sequence of activities interwoven with the material. Whereas this sequence is traditionally called a lesson plan, learning flow draws attention to the central need to maintain flow in 1:1 classrooms. Fortunately, researchers have already developed a rich repertoire of pedagogical activity models over the years. Technology, as a component of 1:1 classroom settings, can further enable the design of these models. Once learning flow has been specified, designers work closely with subject matter experts to implement the details, including the associated material operated in each activity model of the flow.

Learning flow is composed of some basic 1:1 classroom activity modes, including individual, group, inter-group, one-to-class, class-to-one, group-to-class, class-to-group, etc. An example of the individual mode is that every student in the classroom learns quietly with his/her computing device. The device may act as a cognitive tool, an intelligent tutor, or an online information browser. Students have no interaction with others inside the classroom except for the teacher. An example of the class-to-one mode is anonymous answering (or voting) for a multiple choice question, which requires students to make choices on their clicker devices while the teacher is playing the role of a coordinator or judge (Huang, Liang, & Wang, 2001).

Bingo game as learning flow

Well-timed practice is essential for building procedural fluency in arithmetic calculations as well as other skills (Dick, Carey, & Carey, 2001; Gagne, 1985; Gagne, Briggs, & Wager, 1992). However, arithmetic drills render students prone to boredom (McLeod, 1992), make students either distracted or impatient, lower their learning interest, and consequently run contrary to the assessment goal—developing fluency. Game-based pedagogies can effectively shift students' attention from performing repetitious and boring tasks to winning a game, thereby maintaining their engagement in the learning tasks.

We adopt the Bingo game as the learning flow for our content sample for a number of reasons. First of all, it remains to this day a highly popular game, widely played for fun, gambling, and education, with a long history (Delind, 1984; Snowden, 1986). Bingo was initially adapted from a variation of Lotto, namely Beano. In 1929, Edwin S. Lowe, a New York toy salesman, unwittingly came upon a carnival where Beano was being played. It was so popular that he could not get a seat to play. He observed that the players were so addicted to the game that they were reluctant to leave until the pitchman closed the game at three in the morning. At a later observation of the game, Lowe noticed an accident: a player mistakenly yelled "Bingo" during the game when she won. Lowe then started to promote the game under the name Bingo.

Another reason is that Bingo is appropriate for extensive practice—repeating a simple learning task assigned by the teacher. Furthermore, winning the Bingo game requires luck, besides other factors. This lessens the frustration of those students who lose. Finally, Bingo requires a coordinator, identified as the caller. The teacher can naturally play this role (more discussion in the next sub-section).

The learning flow of EduBingo, our realization of the Bingo game in a 1:1 classroom, mainly consists of a teacher's dispatching arithmetic problems and students' answering of those problems (the teacher's dispatching is in one-to-class mode and the students' answering is in individual mode). Figure 1 shows the flow of EduBingo in the 1:1 classroom.

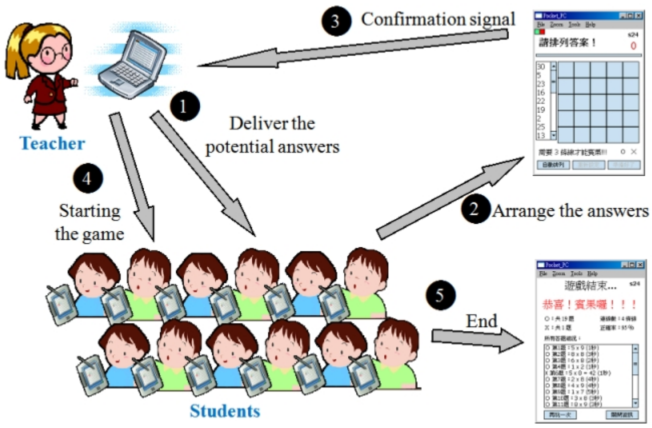


Figure 1. Learning flow of EduBingo

Steps of the learning flow

1. The teacher uses a handheld device to initiate a game session, delivering all potential answers to students' devices.
2. Students' devices receive the answers from the answer pool. Each student arranges those answers on the answer board (see Figure 2).
3. Each student sends out the confirmation message to inform that she is ready to play.
4. The teacher starts the game. A loop of delivering a problem by the teacher and answering the problem by each student is performed, and it cannot be stopped until one student gets "BINGO!" or no more problems can be delivered.
5. The session ends. The students can have a time of reflection according to the system statistics (see Figure 3).

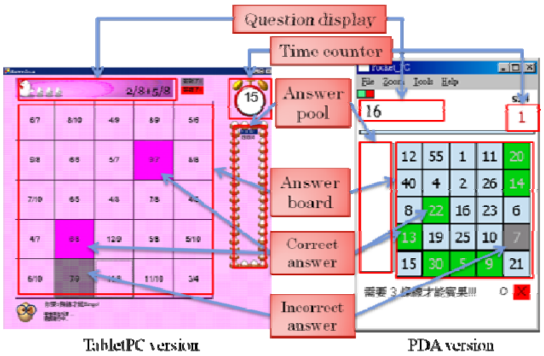


Figure 2. EduBingo board Interface

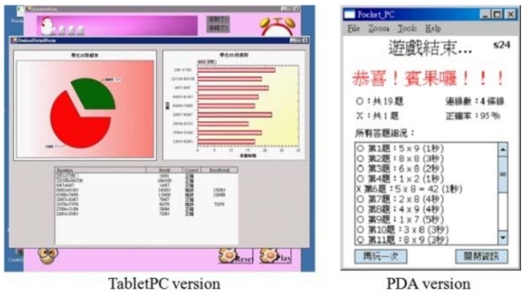


Figure 3. Interface of individual session record after the game session

Fourth concern: Teacher adoption

Remarkable fulfillment of the learning assessment goal cannot guarantee successful adoption. Teachers do not only decide what and how their students learn, but also decide whether technology should go into their classrooms or not. On the one hand, they reject technology adoption for many reasons: not ease of use, changing their daily practice too dramatically, not enough professional training, increasing their work load, even if just slightly. On the other hand, they seek increases in teaching productivity, for example, having computers take care of the lower level tasks so that they may concentrate on higher level tasks such as making decisions for the whole class or individual students. It is our view that increasing productivity is the essence of all technological innovations. Therefore, in addition to the emphasis on measuring the progress of each student towards learning assessment goals, teacher adoption factors are taken into account in all phases of design and evaluation.

Obviously, the teacher's role in a 1:1 learning flow strongly affects his or her mindset towards adoption. In fact, like a traditional classroom, the teacher in a 1:1 classroom plays indispensable roles—the coordinator, the monitor, the leader, the facilitator, the judge, and the personal guide. Furthermore, teachers make students feel valued in the classroom, and they stimulate engagement in the learning tasks (Morganett 1991; Pigford 2001). Even in the individual learning mode, a teacher actively monitors the real time progress of the whole class and makes decisions about actions to be taken for individuals with special needs.

Teacher adoption of EduBingo

The design of what the teacher has to do in EduBingo defines his or her role in that activity. The teacher takes control of the Teacher Supervising Center Component, consisting of Coordination Subsystem (see Figure 4) and Authoring Subsystem (see Figure 5). As a monitor, a teacher uses the Coordination Subsystem to oversee accuracy and efficiency data for each student of the class. The teacher, assuming the role of leader, can start, pause, or end an EduBingo session at any time. To form the problems used in a new session, the teacher composes new calculation problems in the Authoring Subsystem, and may draw upon existing problem sets in the Material Bank.

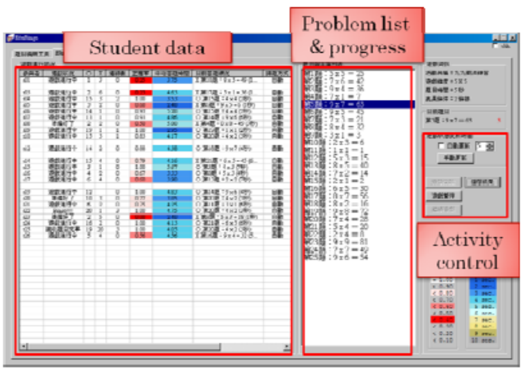


Figure 4. Coordination Interface

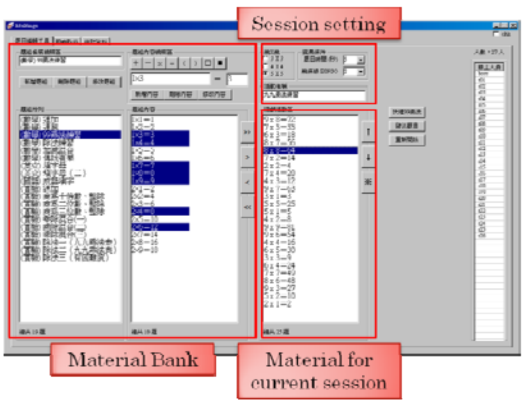


Figure 5. Authoring Interface

Trial Tests

In order to inform the future improvement of the content sample, two trial tests of EduBingo were undertaken in two elementary school classes, one fourth-grade and the other third-grade. The fourth-grade class practiced fraction arithmetic; the third-grade integer multiplication and division. The first test focused on the students while the second centered on the teacher. The students used Tablet PCs in the first test and PDAs in the second, whereas both teachers in the two tests used a Tablet PC. The following sections describe the design and results of these two tests.

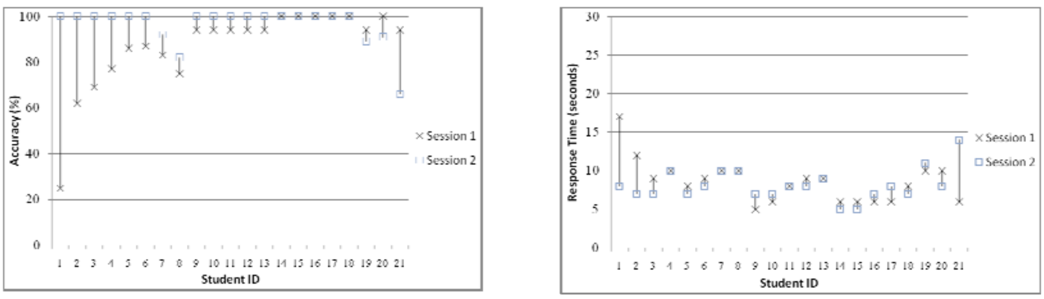
Trial test 1: Student fraction fluency

There were 22 students in the class, twelve boys and ten girls. However, one student data was lost due to unexpected system problems. The trial test started with a five minute introduction to the system. After familiarizing students with the system through playing two warm-up game sessions, no arithmetic calculations but the traditional number matching, the students engaged in two game sessions for practice in using 5×5 matrices EduBingo board in 30-second and 20-second time limits for the first and second sessions, respectively, with the same difficulty level of problems. The winning condition was set as two lines, vertical or horizontal or diagonal, of correct answers on the board.

All students were asked to fill out a questionnaire after the sessions. The students' data log and questionnaires were used to assess the issue addressed by the test. The two real-practice game sessions were compared to examine the improvement in accuracy and efficiency of the fraction arithmetic operations. The students' affect was also explored from the results of the questionnaire.

Results

Figure 6 displays the accuracy and response times in the two practice sessions. The accuracy was calculated as (number of correct answer/number of answers attempted) $\times$ 100%, and the response time was calculated as the average time spent on answering all problems in a session. After the second session, over half of the students (13/21) improved in accuracy (see Figure 6a). The majority of students (16/21) were able to reach the ceiling (100% accuracy) in the second session. It should be noted that after the first session, there were 15 students whose performance was not at the ceiling; however, among them, there were 11 students that reached the ceiling after the second session. It was a bit surprising to us that there were 3 students whose accuracy decreased in the second session. The accuracy drop of student 19 and student 20 might be due to slips (careless answers), but the reason for the unusually large drop (around 30%) of student 20 is unknown to us, albeit due to capers. For response time (see Figure 6b), all the students could answer the problems in both sessions within the given time limits, while most students had similar response times in both sessions, even when the time limit was shortened. The comparison shows that most students improved their accuracy in answering fraction arithmetic problems through practice and maintained their efficiency in performing the tasks on average.



(a) Accuracy (b) Response time

Figure 6. Accuracy and response time between the two practice sessions

The questionnaire contained questions of four dimensions to explore the students' affect. All students showed positive reactions for all dimensions (see Figure 7): When asked to compare EduBingo with paper-based practice exercises, 20 students thought that they would be more interested in EduBingo; 18

more engaged; 19 more focused; and 20 more confident. Twelve of the students indicated that they would learn and practice with more efforts to be able to perform well in EduBingo.

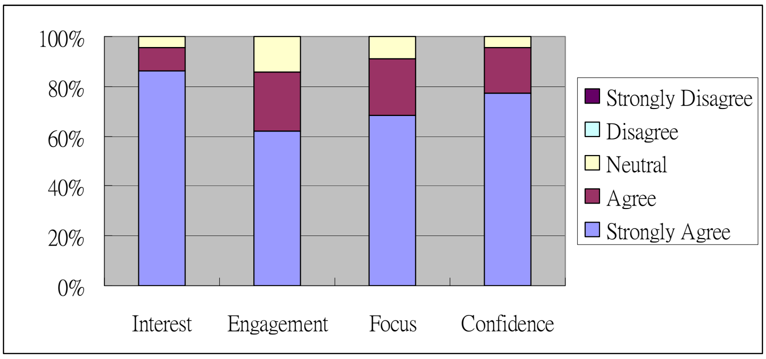


Figure 7. Students' responses on their affect

Trial test 2: Teacher adoption

The second trial test investigated teacher adoption issues. After familiarizing the students with the system through playing one warm-up traditional Bingo session, two sessions for memorizing multiplication table facts and two sessions for practicing division of integers were led by the teacher, with time limits of 10, 8, 50, and 30 seconds, respectively, for each session. Because of the limited PDA screen size, all four game sessions used 4×4 matrices. The teacher was interviewed after the test.

Results

The teacher was positive toward EduBingo adoption, as indicated in the following interview protocol.

Interviewer: *Is the system helpful for student monitoring?*
Teacher: *Teachers are concerned about student learning. The problems I prepared for the sessions have not all been used. For example, when a student Bingos, the game is terminated, leaving some problems unused.*
Interviewer: *EduBingo provides an option that allows the game to continue even if someone Bingos. This way, students can practice all the problems you prepare for them.*
Teacher: *Ok! That means I can use EduBingo for teaching and quizzes.*

It is noteworthy that the teacher's primary concern was student learning and whether the system functionalities can support it.

Teacher: *Is it possible to allow students to compose problems and take on the role of the caller?*
Interviewer: *Yes, it is possible to add these functionalities to EduBingo.*
Teacher: *Good! This would allow the teacher to spend more time on students in need.*
Teacher: *It is a pity that the teacher has to stay in front of the screen all the time. In addition, due to the short period of time for answering problems, it is impossible for me to observe students' behavior. If the students are allowed to play the role of the caller, the teacher will be able to spot poorly performing students.*

The teacher was also interested in whether EduBingo supported functions that allow students to compose problems and be able to conduct the activity on their own, so that she could pay more attention to those students that need help. In addition, she desired a monitor function to assist in locating the students who need help. Both supporting functions suggested by the teacher can be added in the future version of EduBingo. The teacher felt the Tablet PC was too heavy for her to carry when moving about the classroom. This can easily be resolved by using a light handheld device.

Interviewer:	*Did the system provide sufficient information for conducting the sessions?*
Teacher:	*EduBingo provided a good interface for revealing the status of the whole class during the process; different colors indicated student performance. However, I need to know more details about how the students are learning. For example, I want to know if students are answering by guessing. The statistical information cannot provide me with information about whether a particular student was able to answer a problem or not. If a student is frustrated too much when encountering difficult problems, he will give up.*
Teacher:	*Just-in-time assistance is essential in instruction, especially for students with low performance. If just-in-time assistance cannot be provided, more time is needed for remediation.*

The teacher confirmed that monitoring information displayed on her device during the sessions was beneficial. However, the teacher suggested that more information should be provided to facilitate individualized instruction.

Interviewer:	*How do the students like EduBingo for practicing arithmetic calculations?*
Teacher:	*They loved it very much. Maybe EduBingo is similar to some games they often play. You may also consider designing games similar to Mario Bros. for practicing basic arithmetic calculations.*

Finally, the teacher confirmed that the students enormously enjoyed EduBingo and appreciated the design of such a game-like system for learning.

Discussion of Trial Tests

As stated above, the main goal of the two trial tests was to gain valuable data that could be used to shape EduBingo according to the perspectives of students and teachers. According to the results shown above, EduBingo was an effective means to improving arithmetic accuracy but not efficiency. Contrary to our intuition, efficiency was not improved even after repeated practice, which may be attributable to the lack of time constraint on the answering of problems. In order to induce greater gains in improving accuracy, slips may be reduced by requiring students to readdress problems that are answered incorrectly.

In addition to the quantitative measures of accuracy and efficiency, students in the first trial test responded to EduBingo with positive attitudes. Researchers were able to confirm that students were fully engaged when playing EduBingo. Moreover, students maintained high levels of interest, attention and confidence when practicing arithmetic calculations with EduBingo throughout the practice sessions. Positive student affect leads to a high motivation to learn, and is in turn essential to successful learning (Prensky, 2000). We feel that the greatly positive attitude towards EduBingo and high interest in it were not entirely due to the novelty effect of using computers in classroom. In the annals of Bingo history, it has been reported that crowds of people played Bingo games for extended periods of time (Snowden, 1986). Bingo's attraction derives from its characteristic influence on people to remain engaged in its game-play, but whether all students in a class can maintain such enthusiasm for EduBingo over long periods of time merits further investigation. No matter the results of such studies, positive student affect should be considered as a future learning assessment goal to be evaluated in addition to the data received from the students, ensuring more than achievement-based criteria to be satisfied.

The teacher's suggestions, along with the student data, have provided a direction for future improvements and modifications of EduBingo. Reflections on the comments given by the teacher suggest that an improved system should incorporate a mechanism to assist teachers in locating those students in need of help. For example, a student's unusually long time in answering a problem or a sudden increase in the rate of erroneous answers would trigger a detection that is sent to the teacher indicating a student is in need of help. All teachers desire to help students, directly and indirectly, but cannot do so if they are fully occupied with the logistics of a system. In addition, because a teacher cannot be expected help several students in need simultaneously, when possible, the system should utilize intelligent tutors.

Finally, EduBingo is easy to learn and play. The students in the two trial tests only spent a short period of time in the warm-up sessions in order to be familiar with EduBingo, even if some of the students had never played any Bingo game before.

Concluding Remarks

In this paper, we presented our initial guidelines for adoption-based researchers seeking to design and implement 1:1 classroom learning. In particular, we argue that design considerations should place content as the first priority. The primary concern of teachers is teaching effectively, not the cutting-edge technologies that can be introduced into a classroom. In other words, technology enhanced learning should begin by identifying what is to learn, that is, the content sample, then elucidating how well to learn that sample as a learning assessment goal. Next, a learning flow is designed with particular attention to the consideration of adoption by teachers. In our study, elementary level arithmetic calculation was identified as the content sample, and arithmetic fluency was the learning assessment goal. The game of Bingo was used to support the learning flow, and EduBingo was designed and implemented to realize this flow by providing a number of roles for a teacher.

The two trial tests shed light on possible future improvement. As accuracy is obviously more important than efficiency, to diagnose probable erroneous arithmetic calculation procedures in the gaming process and to remedy them between successive game sessions will be our immediate task in enhancing EduBingo. Moreover, as teaching arithmetic calculation procedures necessarily precede practicing such procedures, the incorporation of this teaching into the learning flow including EduBingo is the next major design task. Once this content sample has reached the stage that it is recognized by practitioners as a compelling sample, the use of EduBingo can be expanded to encompass more of the curriculum by working together with teachers to develop materials.

Content-first design can be extended as a general model of design; however, we limit its scope for 1:1 classroom settings so that we can focus on adoption-based research for designing content sample. For instructional design, ADDIE (Molenda, 2003), including Dick and Carey's version (Dick, 1996; Dick, Carey, & Carey, 2001), presents a generic conceptual framework that describes the five phases of instructional planning and creation—analysis, design, development, implementation, and evaluation. There are some correspondences between the content-first design approach and the ADDIE model. For example, both the content sample identification concern and the learning assessment goal concern correspond to the analysis phase; both the learning flow concern and the teacher adoption concern relate to the design phase. Content-first design does not particularly emphasize development, implementation, and evaluation as ADDIE does since they inevitably require iterations for design. However, content-first design places special emphases on putting the learning assessment goal at the outset and treating teacher adoption as an essential part of the design.

Nevertheless, we believe that refinement of this approach will continue as we gain more and more 1:1 research and practice experience. It is true that the learning assessment goal is a good device for gathering information and hence ideas for the subsequent design iterations to improve the content sample. However, there could be hazards or distortions of education (Hussey & Smith, 2002) if learning outcomes are overly emphasized as the primary concern in the design. Actually, the learning assessment goal should not only consider the learning outcome, but also take the learning process into consideration, for example, the student's enjoyment in the process. As such, the definition of the 'learning assessment goal' should be appropriately related to the overall educational goal. Furthermore, developing or adopting an evaluation model such as the Kirkpatrick model (Kirkpatrick, 1998) will help form a firmer foundation for the assessment goal.

Learning design (Koper, 2006; Koper & Tattersall, 2005), an emerging endeavor, aims to describe learning activities in a systematic and machine interpretable representation. A standardized modeling language will allow more flexibility on the part of designers to reuse and share learning activities. In association with learning design, a learning flow so specified could be packaged as a component and adopted into other content samples in different contexts. As this is an emergent issue in the field of adoption-based research, it has not been included in our current study. Learning flow in the content-first design approach currently concerns the design of a sequence of learning activities that achieve the learning assessment goal for an identified content sample.

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References

Abowd, G. D. (1999). Classroom 2000: an experiment with the instrumentation of a living educational environment. *IBM Systems Journal*, 38(4), 508-530.

Anderson, R. J., Anderson, R., VanDegrift, T., Wolfman, S. A., & Yasuhara, K. (2003). Promoting interaction in large classes with computer-mediated feedback. In Wasson, B., Ludvigsen, S., & Hoppe, U. (Eds.) *International Conference of Computer Supported Collaborative Learning 2003*, Bergen, Norway, 119-123.

Chan, T. W., Roschelle, J., His, S., Kinshuk, Sharples, M., Brown, T., Patton, C., Cherniavsky, J., Pea, R., Norris, C., Soloway, E., Balacheff, N., Scardamalia, M., Dillenbourg, P., Looi, C. K., Milrad, M., Hoppe, U., & G1:1 Members (2006). One-to-one technology enhanced learning: An opportunity for global research collaboration. *Research and Practice in Technology Enhanced Learning*, 1 (1), 3-29.

Cottrell, R. (2007). The Economist debates archive: Technology in Education, retrieved June 15, 2008 from http://www.economist.com/debate/index.cfm?action=summary&debate_id=1.

Delind, L. B. (1984). Bingo: Some Whys and Wherefores of a Popular Pastime. *Journal of Popular Culture*, 18(2), 149-156.

Dick, W. (1996). The Dick and Carey model: Will It Survive the Decade? *Educational Technology Research and Development*, 44(3), 55-63.

Dick, W., Carey, L., & Carey, J. O. (2001). *The Systematic Design of Instruction (5th ed.)*. New York: Addison-Wesley, Longman.

Dufresne, R. J., Gerace, W. J., Leonard, W. J., Mestre, J. P., & Wenk, L., (1996). Classtalk: A classroom communication system for active learning. *Journal of Computing in Higher Education*, 7, 3-47.

Gagne, R. M. (1985). *The Conditions of Learning and Theory of Instruction*. New York: Holt, Rinehart and Winston.

Gagne, R. M., Briggs, L. J. & Wager, W. W. (1992). *Principles of Instructional Design*. Texas: Harcourt Brace Jovanovich College Publishers.

Gay, G., Stefanone, M., Grace-Martin, M., & Hembrooke, H. (2001). The effects of wireless computing in collaborative learning environments. *International Journal of Human-Computer Interaction*, 13(2), 257-276.

Halverson, R. & Collins, A. (2006). Information technologies and the future of schooling in the United States. *Research and Practice in Technology Enhanced Learning*, 1(2), 145-156.

Huang, C. W., Liang, J. K., & Wang, H. Y., (2001). EduClick: A computer-supported formative evaluation system with wireless devices in ordinary classroom. In Lee, C. H. (Ed.) *International Conference of Computers in Education (ICCE2001)*, Seoul, Korea, 1462-1469.

Hussey, T., & Smith, P. (2002). The trouble with learning outcomes. *Active Learning in Higher Education*, 3(3), 220-233.

Kirkpatrick, D. L. (1998). *Evaluating Training Programs: The Four Levels*. Berrett-Koehler Publishers.

Koper, R. (2006). Current Research in learning Design. *Educational Technology & Society*, 9(1), 13-22.

Koper, R. & Tattersall, C. (2005). *Learning Design: A handbook on modeling and delivering networked education and training*. Berlin: Springer-Verlag.

Liu, T. C., Wang, H.Y., Liang, J. K., Chan, T.W., Ko, H. W., & Yang, J. C. (2003). Wireless and mobile technologies to enhance teaching and learning. *Journal of Computer Assisted Learning*, 19(3), 371-382.

McLeod, D. (1992). Research on affect in Mathematics Education: a reconceptualization. In Douglas. A. Grows (Ed.) *Handbook of Research on Mathematics Teaching and Learning*, New York, Macmillan Publishing Company.

Molenda, M. (2003). In search of the elusive ADDIE model. *Performance Improvement*, 42(5), 34-36.

Morganett, L. (1991). Good teacher-student relationships: A key element in classroom motivation and management. *Education*, 112(21), 260-264.

National Research Council. (2001). *Adding it up: Helping children learn mathematics*. In J. Kilpatrick, J. Swafford, and B. Findell (Eds.) Mathematics Learning Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.

Norris, C. & Soloway, E. (2002). Keynote speech. *The First IEEE International Workshop on Wireless and Mobile Technologies in Education*, Sweden.

Norris, C. & Soloway, E. (2004). Keynote speech. *The Seventh International Conference on Intelligent Tutoring Systems*, Brazil.

Paley, A. R. (2007). *Software's Benefits On Tests In Doubt - Study Says Tools Don't Raise Scores*, retrieved April 9, 2008 from http://www.washingtonpost.com/wp-dyn/content/article/2007/04/04/AR2007040402715.html.

Pigford, T. (2001). Improving teacher-student relationships: What's up with that? *Clearing House*, 74, 337-339.

Prensky, M. (2000). *Digital game-based learning*. New York: McGraw Hill.

Roschelle, J., Penuel, W. R., & Abrahamson, L. (2004). The networked classroom. *Educational Leadership*, 61(5), 50-54.

Sabelli, N. & Dede, C. (2001). *Integrating educational research and practice: Reconceptualizing goals and policies: “How to make what works, work for us?”*, retrieved April 9, 2008 from http://www.virtual.gmu.edu/ss_research/cdpapers/policy.pdf

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(1), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.

Snowden, R. (1986). *Gambling Times Guide to Bingo*, Gambling Times.

Zurita, G. & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers & Education*, 42, 289-314.