A MATHIC TOUCH

USING TOUCH-SCREEN COMPUTERS IN COLLABORATIVE

ALGEBRA-1 PROBLEM SOLVING

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Abstract
This project aimed to develop a math collaborative tool that works on a Tablet-PC, iPad or other touch-screen device. It focused on middle school algebra students amongst whom collaboration is often hindered by lack of collective focus, waiting for one person to speak, explain or write, group and individual power dynamics as well as uneven platform to present ideas to entire group given these dynamics. The tool consist of a native application that allows students to engage in conversation during problem solving while logging the process and making it visible to both the students and the teacher. The teacher can then decide on how best to assist individual groups. The project was motivated by my daily encounter with problem solving amongst young learners who are adopting and using modern technology to complete many daily tasks, but with limited learning applications for similar technologies. The design process involved the user-centered approach and constantly checked with the students and teachers for whom the tool is intended.
An initial design study involved assessment of students’ collaboration in two situations; one where collaboration was necessary to complete the task while in the second, collaboration was desirable, but not necessary. The assessment during this study involved the comparison of comprehension levels and grasp of underlying features – surface and deep, of patterns used in the puzzle.

Introduction
The advent, adoption and increasing use of computers, wireless devices and networks in K-12 schools has led to new opportunities of effecting different learning techniques, amongst them collaboration. Recent research on cooperative learning (Barron, 2003 and Slavin, 1995) shows that despite the disagreements amongst educational researchers about why cooperative learning methods affect achievement as well as under what conditions cooperative learning has these effects, there is general consensus about the positive outcome of such cooperative learning. In
the K-12 classroom, student collaboration in problem solving plays a role in making subject matter accessible (Slavin, 1995). The importance of collaboration at this level is evidenced by its inclusion as a competence requirement for new teachers by state credentialing bodies such as in California\(^1\). In terms of networks, most public schools in the United States are connected to their school district network and possess a variety of computers, technologies and equipment\(^2\). In addition to this, middle school students are increasingly using mobile devices to access networks, including their school network\(^3\), gaining valuable digital and online skills. However, these capabilities are underutilized by educators partly because of the limited scope of available applications as well as a lack of understanding of the wider implications of technology use in schools (Kleiman, 2000). This project aims at improving student collaboration in the algebra-1 class by supporting conversation amongst the students. It will also demonstrate how information collected during problem solving might be used to enhance immediate as well as ongoing understanding of concepts. In addition to this, it will inform the teacher’s decision-making when it comes to initiating, supporting and modifying collaborative learning in the algebra class.

Once fully functional, the tool will enable students to help initiate and determine the direction of their collaborative effort - for instance deciding when they need help and requesting it from other students. Taken in a wider context, students will gain meaningful interaction with technology and with each other as they initially act on the periphery, then progressively as creators and even co-evaluators of their work in a model resembling participation in communities of practice (Lave and Wenger, 1991).

This project arises from my daily experience teaching urban middle school student and recognizing that students often learn better from each other through deliberately structured teacher-initiated collaborative activities. At the beginning of the project, the expected challenges

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\(^1\) Element 3.5 – Formative Assessment for California Teachers (FACT) Pilot/2008-2009
\(^2\) US Department of Education: Education Technology in Public School Districts, Fall 2008
\(^3\) Teens Social Media and Health - NYPH Dept Pew Internet: http://www.pewinternet.org
included combining and aligning the diverse software and hardware components required for the full functioning of the project. The design process employed the user-centered model where observations were conducted to determine needs, followed by the development of some concepts that were then shared with users for feedback. A prototype was then developed and tested with users, providing new insights that led to iteration of the design.

**Learning Problem**

One of the most commonly used collaborative tools in today’s classrooms involves Classroom Response Systems (CRS), which enable the instructor to poll and collect statistical data on the choices selected by students. While this information is important, these tools leave out the conversation component of collaboration, as well as details on patterns, history and trends, which might be used to extend the function of these devices, such as error detection and correction. Other collaborative studies such as the NSF funded River City (Dede, 2009) multi-user environment have explored the use of simulated settings in biology and epidemiology, producing interesting insights. However, few such studies exist for the middle school algebra-1 class environment.

There has been increasing attention on how computer networks impact learning as seen from the volume and variety of recently published studies on this topic. In one such study involving students in a middle school math class, White (2006) notes that ‘the sharing of mathematical objects through interactive devices broadens the “bandwidth” of classroom collaboration, expanding the range of participatory forms through which students might contribute to the work of a group and enhance their own learning’. This points to the role of (wireless) interactive devices, as well as collaboration towards students’ individual learning gains. These students used handheld wireless devices to manipulate and view changes to polynomial functions resulting from changes made by students in their group, all working as ‘cryptographers’. The results of
this experiment show that students demonstrated gains directly attributable to the mode of instruction afforded by the use of the wireless handheld devices.

Collaborative learning relies on communication between and within learners. How effective this communication occurs might as well be the determining factor as to whether collaboration succeeds or not, or even happens in the first place. Herman & Kienle (2008) posit that computer-supported learning systems need to fulfill certain socio-technical conditions. Amongst the communication-specific design recommendations for such systems, they point out the following:

- Employ a communication model which takes facilitators as a third party into account and promotes the design of features which support specific communication acts such as initiation, stimulation, etc.

- Prepare students to be able to act communicatively and to be aware of the specific temporal structure or problems of interruptions that are inherent in asynchronous communication. Provide functions that make this awareness more feasible.

The goal therefore, is to develop a tool that will first and foremost allow conversation between collaborating students, capture additional data beyond the statistical counts, and maintain a history of the interactions. It will also inform the instructor so that she can make informed decisions on when to intervene as well as the nature of help to provide for the students.

This project arose from personal experiences encountered as a high school math teacher in bay area urban schools. The initial project focused on homework feedback, but changes were made soon after conducting the first round of learner studies. I found out that some schools still considered homework and the resulting feedback as an important part of learning. However, the shear volume of paperwork involved, as well as the time constraints arising from students and teachers daily schedules continue to make it almost impossible to achieve a meaningful use of homework feedback. Hence the original project involved students digitizing their homework
assignments using a micro-camera, then getting the files automatically transmitted to a server via wireless network at school. The micro-camera would be embedded into the flash/key drives currently common amongst students. The flash drives would also be modified to incorporate wireless capability. Once the student assignments were delivered to the server and tagged appropriately into corresponding student files, they would be accessible to the teacher for grading using a tablet-PC or iPad- kind of computer. The updated, graded copy would then be saved back into the student folder. Students, parents and teachers could then view these files on computers or wireless devices.

After conducting initial studies to determine the viability and effectiveness of the proposed solution to the above problem, several insights were revealed. The first one revolved around students' limited ownership of the kind of mobile phones that would enable them to access their graded homework any time, anywhere. Secondly, it was found that introducing a new use of their mobile phones did not necessarily serve as a motivation to regularly use it for homework feedback. In addition, given that some students would not have such web-enabled phones for a while, it would be impossible to require an entire class to use the tool. This led to a new exploration that led to the current project, which revolves around collaboration in the middle school math class using digital interfaces.

**Design Approach**

In exploring some of the best design practices, Berkun (2007) discusses the importance of “framing” problems by comparing them with similar ones that have been solved. Pen, paper, white boards and physical grouping are the competitors here, and the design approach takes into consideration the reasons why these forms of initiating collaboration have endured the test of time. Other insights were gained from Nielsen’s (1990) usability heuristics, which provided a
criteria for testing the prototype. These heuristics help to highlight aspects of the tool that effect, impede or violate basic user considerations.

This tool also aims at transferring some responsibilities to the student, in line with developing communities of practice where students are progressively guided into performing central roles in learning (Lave and Wenger, 1991). User feedback during the development, prototyping and testing played an important role in this project. This followed the belief that observing user interaction with the tool yields the best insights on how to improve or modify features that confuse or deter the user from achieving the intended goals. Best practices on Participatory Design, for instance Muller’s (1993) discussion on methods, techniques and practices that can lead participants to combine diverse knowledge into new insights were applied.

There exists some confusion and disagreement amongst educational researchers about why cooperative learning methods affect achievement as well as under what conditions cooperative learning has these effects. However, there is general consensus about the positive effects of such cooperative learning. In one recent paper, Slavin (1995) examines the theoretical models explaining the achievement effects of such cooperative learning. He supports the notion that collaboration enables learners to engage deeply in learning activities, leading to evidence of measurable gains. The perspectives he expresses can serve as important considerations for learning designers in developing environments and tools that encourage, initiate, support and foster collaboration in general.

The learner study explored the effect of middle school students’ collaboration in solving a puzzle that simulated a networked, digital environment: the participants remained silent, acting as if the rest of the team were physically removed from their table. We set out to determine the impact of participation in two scenarios, one deliberately set up to require every group member’s engagement, while in the second configuration, one or more members could refrain from
participating. After solving the puzzle, the students were asked to redraw the shapes that each of their team members created in order to demonstrate deeper understanding of the entire set comprising the puzzle. They were not forewarned about this last requirement. These images were rated for resemblance to the actual shapes.

This learner study, modeled along a networked, computer-mediated environment examined the effect of collaboration on the ability to notice and redraw features of the pieces used in a math puzzle. It involved 49 middle school algebra-1 students, who were split into groups of 4 per team and assigned a proctor that recorded the statistics. Two conditions were set up: one requiring that all group members participate - and had only the required number of puzzle pieces, while the other desired every member’s participation but did not necessitate it for the team to successfully complete the task. Participants in this last category had extra, shared puzzle pieces.

Each student was given three pieces of a puzzle, which were passed around the team until everyone had a complete but different square. After the pieces were collected, they were asked to redraw outlines of each of the squares that had been created by the team. The time taken to complete the task, number of exchanges, and accuracy of the redrawn figures were used to analyze the results.

It was projected that the teams which were required to collaborate would take longer times, redraw more correct squares, and that it would take them more moves to complete the task compared to the other teams. The results showed that required collaboration teams in fact took
shorter times, initiated less moves, but as projected, were able to redraw more correct squares than the other teams. Further, a new unexpected scenario arose; three of the ten groups were unable to complete the task – they “got stuck”.

**Why this technology for this problem?**

Wireless technology is abundant in most urban schools, with a few exceptions. Devices based on such wireless technology are also on the rise, increasing the possibility that future tools based on this technology will find a wide acceptance and support. The nature of touch-screen computers and devices also presents an interface that naturally supports the kind of interaction envisioned in this project.

**Description of the anticipated "product"**

![Diagram of General Structure of Collaboration Monitor](image)

Fig 2. General Layout of Tool
In one scenario, 4 students are collaborating to solve the popular Diophantus’s riddle to determine how long he lived. The following table shows the tags that are used for the different elements:

Table 1. Tags Required For Experience Prototype

<table>
<thead>
<tr>
<th>Step</th>
<th>Student/ID</th>
<th>Gesture</th>
<th>Sign</th>
<th>Variable</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alex/#1</td>
<td>S – Select</td>
<td>+</td>
<td>D</td>
<td>½</td>
</tr>
<tr>
<td>2</td>
<td>Ben/#2</td>
<td>I – Insert</td>
<td>−</td>
<td>S</td>
<td>¼</td>
</tr>
<tr>
<td>3</td>
<td>Chen/#3</td>
<td>W – Withdraw</td>
<td>×</td>
<td>¾</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Dinah/#4</td>
<td>M – Move</td>
<td>÷</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>T - Text</td>
<td>=</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>
During the next experience prototype, four middle school students (two 7th and two 8th graders) were presented with the Diophantus’s riddle (see Appendix) and its interpretation in prose. They sat around a table and were given a warm up activity involving collaborating to plan the upcoming birthday for one of the participants. The teacher participated in this warm up and helped model good collaboration. They were then given the riddle and allowed time to read and understand it.

They were informed that they did not have to write but the teacher would use a PowerPoint screen to list the steps they came up with. This screen was visible to all. The students started by discussing the name, making comments about the son’s short life, wondering if they had enough information, and trying to understand the sequence of events. They then spend some time on what the 4 years between the son and father’s death.

Student #1 pointed out that the dad’s age is X and so 1/6th of X should be his childhood.

#2 asked how they would figure out the age without at least one person’s age.

#3 responded that they would use all the fractions to create an equation.

They got stuck at this point and the teacher then provided the following information:

1. You need the following signs + - ´ = ( )
2. The variables D and S

3. Numbers $\frac{1}{2}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{12}$, 2, 4 and 5

They then started talking about getting rid of fractions since #2 pointed out that he dislikes fractions. He mentioned reciprocal and #3 inquired what this was, whereby #4 gave examples of 2 and $\frac{1}{2}$ as reciprocals of each other.

#1 then declared that if the dad’s age is D, then the first part of his life is $\frac{1}{6}D$.

#2 said that he couldn’t make sense of the problem.

#1 then contributed that they need to add $\frac{1}{6}D$ and D

They then got stuck again and the teacher led them by showing the equation involving D and S. (D = 2S and S = $\frac{1}{2}D$)

Some light bulbs turned on amongst the students and there was some conversation starting with #4, but without new steps emerging. The teacher eventually showed them the solution. #1 ended by pronouncing, “math is haaaard!”

The tool will consist of digital interfaces such as tablet-PC or iPad connected to a central control system through wireless routers. The central controller will be used to log the interactions between users, but will also include an intelligent system to initiate certain kinds of collaboration configurations, capture errors and possibly correct them, as well as provide summaries that will enable the instructor to structure new collaboration sessions.

**Assessment plans and procedures**

The current product will continue to be tested with users for purposes of improving and iterating the design towards a tool that will be made available to iPad users and later, other touch-screen device users. Assessment of the finished tool’s effectiveness will consist of comparing student’s problem-solving skills between two points: before and after several weeks of using the tool. Teachers’ feedback will also be sought through interviews and questionnaires. The data
collection will therefore consist electronic logs, questionnaires and interviews. The student assessment will involve collecting student responses and evaluating them for quality in terms of levels of comprehension of concepts covered, as well as demonstration of understanding of surface and deep features of the concepts. Since this project is ongoing in order to produce an industry level product, much assessment and improvements will be made in the coming months.

Conclusion

This project has so far yielded a prototype that now works on an iPad and is currently being employed in obtaining user feedback as we improve on the existing features. It will continue to evolve as additional insights are gained and applications programmers contribute their expertise to the project. The goal is to produce an app or a suite of apps that will run on touch-screen devices such as the Tablet-PC and iPad.
References


Appendix

**Diophantus's Riddle**

*Source: [http://mathworld.wolfram.com/DiophantussRiddle.html](http://mathworld.wolfram.com/DiophantussRiddle.html)*

Diophantus's riddle is a poem that encodes a mathematical problem. In verse, it read as follows:

'Here lies Diophantus,' the wonder behold. Through art algebraic, the stone tells how old: 'God gave him his boyhood one-sixth of his life, One twelfth more as youth while whiskers grew rife; And then yet one-seventh ere marriage begun; In five years there came a bouncing new son. Alas, the dear child of master and sage After attaining half the measure of his father's life chill fate took him. After consoling his fate by the science of numbers for four years, he ended his life.'

Stated in prose, the poem says that Diophantus's youth lasts 1/6 of his life. He grew a beard after 1/12 more of his life. After 1/7 more of his life, Diophantus married. Five years later, he had a son. The son lived exactly half as long as his father, and Diophantus died just four years after his son's death. All of this totals the years Diophantus lived.

Let \( D \) be the number of years Diophantus lived, and let \( S \) be the number of years his son lived. Then the above word problem gives the two equations

\[
D = \left( \frac{1}{6} + \frac{1}{12} + \frac{1}{7} \right) D + 5 + S + 4
\]

\[
S = \frac{1}{2} D.
\]

Solving this simultaneously gives \( S = 42 \) as the age of the son and \( D = 84 \) as the age of Diophantus.