Discovery learning in mathematics education: Using multimedia technology to reach teachers

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Discovery Learning in Mathematics Education:
Using Multimedia Technology to Reach Teachers

MSSE Master's Project

Submitted to the Faculty
Of the Master of Science Program in Secondary Education
Of Students who are Deaf or Hard of Hearing

National Technical Institute for the Deaf
ROCHESTER INSTITUTE OF TECHNOLOGY

By

Rachel C. Lewis

In Partial Fulfillment of the Requirements
For the Degree of Master of Science

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June 12, 2006

Approved:

Harry G. Lang
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Discovery Learning in Mathematics Education: Using Multimedia Technology to Reach Teachers

Abstract

Being a teacher requires the dual skills of both knowing a content area and knowing effective methods for teaching that content. Teachers of deaf students, however, frequently have more training related to deafness rather than their content area. At issue is access to resources which could remedy this problem. This paper outlines the development of an online workshop which will serve as a pilot project to explore ways to get pedagogical and content knowledge from skilled professionals to both teachers in the field and students in teacher preparation programs. The mathematical preparation of teachers of the deaf was reviewed and a workshop topic selected before designing a script and visual aids for the workshop itself. After the workshop was recorded, materials were compiled into a multimedia program, and feedback was solicited from three audience types. The feedback indicates that there is indeed an audience for this type of learning experience, although some modifications might be made.

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Master’s Project
June 2006
Acknowledgements

No project of this type is possible for a single person to complete. The author would like to thank the following individuals for their invaluable assistance and support in the completion of this project:

- Dr. Harry Lang for serving as mentor, advisor, and all-around source of knowledge and humor during the long process
- Dr. Christopher Kurz for his suggestions related to the workshop content and for serving as the on-screen talent for the workshop video
- Tom McNeal for handling the technical “nuts and bolts” of the project and for extending the opportunity to develop the workshop in the first place
- Stacy Bick for her assistance and expert direction during the studio filming process for the workshop video
- Finally, the anonymous teachers for their willingness to view the workshop and offer thoughtful suggestions and sincere encouragement.
Project Overview

This project is an asynchronous online workshop, consisting of a videotaped lecture and PowerPoint slides which are viewed concurrently, and a discussion board hosted on a separate website. The video portion is approximately thirty minutes long; participation in the workshop involves pausing the video to respond to questions or prompts on the message board, so completion requires an average of one hour. The presenter utilizes American Sign Language (ASL), and both a voice-over and captions are available (captions available on Windows computers only). Users viewing the workshop using a PC must wait approximately five minutes on a high-speed connection for the workshop to download; users viewing on a Macintosh computer can begin streaming the video immediately. The workshop may currently be found at the following URL; however, it is uncertain how long it will remain posted at this site:

http://stream.kent.edu/tmcneal/DiscoveryLearning7.htm

Project Objectives

This workshop has been designed as a pilot project to determine whether efforts should be made to create similar workshops focusing on a variety of content and pedagogical topics. It will also aid in identifying improvements or adjustments which should be made to the curricular design or technical aspects before such efforts for further workshops are made.

Rationale and Review of Literature

In this time of increased standardized testing linked to school accountability, as well as international comparison and competition, teachers are coming under an increasing amount of scrutiny. Mathematics is an area that is being particularly examined, as widely publicized international tests have shown the United States to be behind other countries. Also, with the ever-booming development of technology, and society’s reliance on it, mathematics and the
associated problem-solving skills are becoming more and more necessary for both careers and everyday living.

To answer the call for better mathematics education, reform has taken place on many levels. Standards have been developed on national, state, and sometimes local level. Teacher education programs have altered their curriculum and pedagogical emphases. Many large-scale assessments now include constructed-response or open-ended items, rather than exclusively selected-response items. There are some indications that headway is being made.

What about the specific area of deaf education? Are deaf students being prepared mathematically for life in the twenty-first century? Are teachers of deaf students prepared to teach mathematics effectively to their students? If not, what can be done about it? These last two questions will guide the remainder of this review. We will briefly review literature pertaining to both (1) the mathematical and (2) the pedagogical preparation of mathematics teachers of the deaf, and consider a possible course of action based on our findings.

**Mathematical Preparation**

Over the last several years, the National Council of Teachers of Mathematics (NCTM) has released a series of position statements regarding the appropriate teaching of mathematics. One of these (NCTM, 2005) is regarding “highly qualified teachers.” NCTM asserts that all students have the right to be taught mathematics by such a teacher, and define a “highly qualified” teacher as one who both knows mathematics and is able to guide students through the learning process. The council adds that such a teacher understands how students learn mathematics, maintains high expectations for all students, and continually engages in professional development activities to expand their own knowledge and skill.
To this end, NCTM not only suggests, but *expects* high school mathematics teachers to have completed courses equivalent to a mathematics major, and middle school math teachers equivalent to a mathematics minor — *at least*. Yet in a study of teachers who taught mathematics to deaf students at schools for the deaf, Pagliaro (1998a) found the following: Of grade 5-8 teachers, 49% took a course on college algebra, trigonometry, and/or elementary functions, and 30% took a course on calculus. Of grade 9-12 teachers, 85% took college algebra, and 61% took calculus. Yet for a mathematics major, college algebra and calculus are only the beginning of their coursework.

This is, in fact, more than a suggestion from a professional organization. Recent legislation in the form of the No Child Left Behind Act of 2001 (NCLB) also requires that *all* children be taught by highly qualified teachers by the 2005-2006 school year. This means holding a bachelor’s degree (at minimum) and demonstrating competency in the subject area to be taught, either through rigorous testing, completion of an academic major, or equivalent coursework (NCLB, 2002). Steffan (2004) notes that this news dealt a serious blow to educators of the deaf, as well as to special educators in general. Teachers in these areas already require a large number of hours to obtain a degree and certification, and with the passage of the law, they are required to be experts in any subject area they teach as well. According to the results found by Pagliaro, many mathematics teachers of deaf students do not have that “equivalent coursework” under their belt.

In another survey study, Kelly, Lang, and Pagliaro (2003) found similarly disconcerting numbers regarding educational background and certification. Again, those surveyed were mathematics teachers of deaf students, and approximately 130 teachers participated. Forty percent of those teaching in center schools reported having a bachelor’s and/or master’s degree
in either mathematics or mathematics education. In mainstream settings, 67% of teachers in inclusive classrooms reported having such degrees, and only 15% of teachers in self-contained classrooms. The proportion of teachers certified in mathematics was similar: 41% of center teachers, 76% of mainstream/inclusive teachers, and 9% of mainstream/self-contained teachers. Clearly, a number of deaf students are learning mathematics from teachers who do not have formal qualifications in the area.

**Pedagogical Preparation**

However, there is more to teaching mathematics than simply having a strong grasp of the material. Several studies show that beyond mathematical knowledge, there is great need among teachers of the deaf to obtain further training in mathematical pedagogy. Pagliaro and Ansell (2002) investigated the use of story problems in deaf elementary classrooms. They found that story problems are presented less often to younger students, contrary to the suggestions of research and the NCTM standards, which indicate significant gains when problem-solving is integral and frequent.

A study by Kelly, Lang, and Pagliaro (2003) looked specifically at problem solving and showed there is a need for increased teacher education in that area. In particular, teachers of deaf students tend to focus more on concrete problem-solving strategies, rather than more analytic strategies. Also, students are given more exposure to practice exercises, rather than “true problems.” In this case, and throughout the mathematics literature, practice exercises refer to problems that follow a set format and which students are expected to solve in the demonstrated way; in other words, rote memorization. True problems, on the other hand, may have more than one solution, many paths to solving, extraneous information, and so on. Such problems enable
students to develop independent problem-solving skills, yet many teachers do not give them that opportunity.

Likewise, a study by Kelly, Lang, Mousley, and Davis (2003) examined issues deaf learners have with relational language in problem solving and indicated teachers need to learn more about addressing such issues. One problem may be that teachers are encouraging their students to memorize set rules, such as, "More means addition." However, in some mathematical problems, the word "more" will be used, but the required operation will be subtraction. These types of situations are particularly problematic for deaf students, especially in cases where words such as less, shorter, fewer, etc. are used, but the operation needed is the opposite of that which would be expected.

In her study of teacher preparation, Pagliaro (1998a) also discusses courses taken in mathematical pedagogy. Grades 5-12 teachers are more likely to have taken a course on methods of elementary mathematics than those of middle or high school. She also discusses in-service training related to mathematics, awareness of the NCTM Standards (which at the time of the study were three separate documents, prior to the 2000 release of *Principles and Standards*), and availability of journals. In another study, Pagliaro (1998b) examined the background of NCTM Standards implementation in general and the level of implementation in deaf education, finding that awareness and implementation of the standards was much lower in deaf education settings. In fact, administrators were generally more familiar with the three standards documents than were the teachers.

There is more to the No Child Left Behind Act than a demand for highly qualified teachers. A large part of the act demands accountability, demonstrated in the form of core area tests to be passed with proficiency by *all* students. This means teachers need not only be
qualified in their area, they must also be effective in teaching their content. Ironically, many
deaf students' test results are "hidden" by being pooled with their home district while the student
attends a special school for the deaf; approximately one-third of the states do not require their
schools for the deaf to be reported independently (Cawthon, 2004). While some may argue the
appropriateness of holding schools with a sole population of "disabled" students to the same
standards as their non-disabled peers, the fact remains that deaf students have equal rights to be
taught by teachers who are qualified in their area and can teach it well.

Future Course

The conclusion is that many teachers didn’t learn about math pedagogy during college,
and also frequently aren’t getting information about it in the field. The recommendation is to
attend seminars and workshops in both math education and mathematics itself. Pagliaro (1998a)
also recommends the following: "Teacher educators whose interest is in the mathematics
education of deaf and hard of hearing students should offer mathematics institutes at various
locations across the nation" (p. 378). This can be difficult to do physically. Many teachers of
the deaf are fairly isolated, working in areas where their numbers are small. Teachers of the deaf
in rural areas, particularly, may be alone or one of few in a large area, and the distance to a
workable location for such an institute may be prohibitive.

In an article on teacher preparation programs in deaf education, Johnson (2004) addresses
this concern, noting the need for "virtual learning opportunities." In what is known as the
"Information Age," such virtual learning opportunities are more viable than ever, with various
technologies being developed, streamlined, and rapidly made affordable. While the technology
is there, the product must still be developed. Online workshops have been created and used by
many organizations, including NCTM. Their E-Workshops utilize video, PowerPoint slides,
web pages, Microsoft Word documents, and audio over a telephone line. Dr. Monique Lynch, NCTM's Director of Professional Development Programs and Services, indicates that they have never had a request for captioning or TTY, though she believes their software has some type of captioning capability (personal communication, October 11, 2005). While efforts should certainly be extended to make NCTM's workshops available to teachers who are themselves deaf or hard-of-hearing, there is also a need for workshops designed by those who understand the specific needs of deaf students.

This need was one impetus for the development of the Join Together Project. Fulfilling that need requires that groups such as Join Together examine the various forms of technology which are available, and determine which will best serve their purposes. Various software packages are available, which may allow either live or asynchronous broadcast of video, coordinated slides, and in some cases, linked discussion boards. Such software, paired with collaborative groups like Join Together, can ease logistical problems and make the "mathematics institutes" suggested by Pagliaro more widely and conveniently available.

Clearly, there are many issues faced by institutions trying to prepare teachers of the deaf, particularly in the area of mathematics. A large number of teachers do not have formal training, or even certification in mathematics, yet that is what they find themselves teaching. They are unaware or inadequately aware of the established national standards and their implications. They also may be unaware of mathematical pitfalls deaf students may particularly face, and what they can do to effectively help students navigate such areas. Many teacher preparation programs may not have the resources available to address all these issues on their own, and teachers who are already in the field may be far distant from experts who could provide additional training. Yet the need is there for increased pedagogical and content preparation regarding mathematics.
Thus, interested parties will be looking to collaborative technologies such as online multimedia packages, which may serve to transmit the knowledge and expertise to teachers of the deaf in any stage of their career and in any location.

**Mathematics Education Today**

In order to determine an appropriate topic for such an online workshop, consideration must be given to the current knowledge of best practices and relevant issues in mathematics education. As mentioned above, NCTM released the *Principles and Standards* in 2000, outlining goals in content and process for students in elementary and secondary school. The first versions of the Standards were introduced as a series of documents in the 90’s, with revisions and refinements culminating in the current document. These standards prompted a new look at how mathematics were being taught and what students needed to be able to do with mathematics upon leaving school.

The result was a determination that most students only took required courses in mathematics, yet in the workplace found they needed math skills they did not have. Many students knew formulas, but because they didn’t understand the basis of these formulas, they did not know how or when to use them in real-life situations. Buchholz (2003) summarized that the feeling in the field of mathematics education was that change had to begin with teachers — ensuring they knew a lot more mathematics than their students, and that they began to teach it differently.

Another result of the NCTM Standards was the development of new curricular materials, often referred to as standards-based curricula. These materials generally emphasize student engagement in understanding mathematics, often through problem-solving (Schoen, Cebulla, Finn, & Fi, 2003). Schoen et al. conducted a study indicating that access to appropriate materials
is not enough; teachers also need professional development and training to learn how to use the materials in a way that is in accord with the principles of the NCTM Standards. Differences in teacher implementation frequently result in a difference in student achievement.

When using standards-based curricula with an emphasis in problem-solving, the content knowledge of the teacher again becomes key. Van Dooren, Verschaffel, and Onghena (2002) conducted a study with preservice teachers in Belgium, comparing the future teachers’ own problem-solving tendencies with their evaluations of student approaches to various problems. In particular, they investigated the value given to arithmetic versus algebraic solutions in different problem situations. They found one subset of participants gave a higher score to the arithmetic approach to a particular problem because the future teacher could not grasp the algebraic approach him- or herself. This is clearly problematic; a teacher must be prepared to follow a student’s line of reasoning and determine whether the student’s solution is valid or not. Such preparation comes only with a solid foundation of mathematical understanding.

While the demands of learning a different way of teaching, using different materials may seem overwhelming to veteran teachers, there are indications that the effort is worth it. Several studies have been conducted evaluating student achievement in standards-based classes. One such study indicated that students who were involved in such a mathematics course for at least two years scored equal to similar students in a “traditional” math course on standardized tests, and scores were significantly higher in two areas: data analysis, probability, and statistics; and algebra. In two of the districts studied, the standards-based students scored significantly higher in other strands as well (Reys, Reys, Lapan, Holliday, & Wasman, 2003). Although this study focuses on the use of standards-based materials, the authors do acknowledge the importance of
how the materials are implemented. All teachers in the study’s standards-based classrooms had received professional development training related to the Standards.

**Workshop Format**

Finally, just as teachers must consider how they can most effectively teach their students, designers of an online workshop must consider how they can best present their material and make it available to a wide audience. Sousa (2000), among many other sources, indicates that the more cognitively engaged a student is, the more he or she will learn and retain. Anyone who has ever sat in a class or seminar and found their mind wandering knows how true this is. Yet this presents a problem for the online workshop. One advantage of designing a workshop to be accessed online asynchronously (meaning pre-recorded, non-live) is that it is then available any time of day or night — a huge advantage for busy teachers or college students. Yet this very advantageous feature also severely limits interactivity.

A compromise may be reached based on a study by Dowaliby and Lang (1999). In this study, the authors investigated the effectiveness of various adjunct aids in increasing retention of information presented in a passage of text. The students were divided into five groups, each receiving a different combination of materials: (1) text only, (2) text and ASL movies, (3) text and animation movies, (4) text and adjunct questions, (5) text and all three additional aids. Their results indicated increased retention when adjunct questions were used, and they hypothesized that this was due to increased cognitive engagement when answering questions as opposed to the more passive activities of reading and viewing movies. While the situation for an online workshop is somewhat different from that of the study, a similar style of engagement may be attempted by including prompts for viewers to respond to, perhaps by using an online discussion board.
Activities

The first step in designing the workshop was to select a topic related to mathematics education. The decision to focus on discovery learning was primarily based on the author's familiarity with that practice and its alignment with "standards-based" teaching. In August of 2005, the script for the workshop was drafted with three major components in mind: (1) introduction and background supporting student-centered learning, (2) samples of approaching mathematical topics using the discovery learning method, and (3) conclusion summarizing the workshop and leading to further study. Along with the script, PowerPoint slides were designed to support, but not distract from, the content of the lesson.

During September 2005, the script was practiced by the presenter, Dr. Christopher Kurz, and test footage was filmed to practice pacing with the author voicing simultaneously with Dr. Kurz's presentation. Also that month, the formal lesson was filmed using professional studio equipment at the National Technical Institute for the Deaf. The following month, the film was reviewed to develop a transcript which matched the voiceover exactly; this transcript would be used to create the captions, and also to indicate where slide transitions should occur. Finally, all the materials were sent to a technical advisor, Tom McNeal, at Kent State University, who inserted the captions and integrated the material into one web page using Microsoft Producer.

In early 2006, the evaluation survey to be used for collecting feedback was drafted and revised. Approval was obtained from the Institute Review Board (IRB) to collect feedback from individuals. Volunteers were solicited through various means, and feedback information was gathered, as described in the section below.
Implementation

Feedback was sought from three related audiences: (1) students in teacher training programs who sought to teach mathematics to deaf students, (2) current mathematics teachers of deaf students, and (3) college faculty responsible for training future teachers. In addition, it was hoped that a balanced mix of participants would use PC and Macintosh computers. Participants came from two distinct sources — colleagues and classmates of the author, and respondents to an invitation sent through the mailing list of the Association of College Educators of the Deaf and Hard of Hearing (ACE-DHH).

Each participant was sent instructions for accessing the workshop, posting on the discussion board, and submitting feedback (Appendix A). Feedback was collected using an online survey on RIT’s Clipboard system (Appendix B). Some survey items consisted of rating on a five point Likert scale, while other items were open-ended and sought detailed information or suggestions. A total of eight individuals participated and offered feedback — three pre-service teacher candidates, three current teachers of deaf students, and two college faculty. In addition, one college faculty member and one current teacher of deaf students used Macintosh computers to view the workshop. The desired balance of PC/Macintosh users could not be achieved due to technical considerations (see below).

Results and Discussion

Overall, the response to the workshop was positive. All eight participants indicated that they would very much like to see more workshops done in a similar way. However, the workshop as developed clearly has strengths as well as weaknesses.
Technical/Format Considerations

One major technical shortcoming was encountered immediately — the Microsoft Producer software would not display captions on Macintosh computers. Prior to and during implementation, it was found that compatibility issues with Macintosh computers went further, as a number of potential users meeting system requirements were still unable to view the workshop. Some had sound but no video, while others could not open the workshop at all. This is certainly something that should be looked into before producing additional workshops.

For those who were able to access the workshop, technical matters seemed to proceed smoothly. Table 1 summarizes the ratings on survey items related to technical aspects of the project, where 1 is “Strongly Disagree” and 5 is “Strongly Agree.”

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>The signing in this online program was clear.</td>
<td>4.75</td>
</tr>
<tr>
<td>The captions in this online program were easy to read.</td>
<td>4.83</td>
</tr>
<tr>
<td>The captions in this online program were synchronized with the sign.</td>
<td>3.50</td>
</tr>
<tr>
<td>The captions in this online program were synchronized with the speech.</td>
<td>3.25</td>
</tr>
<tr>
<td>The slides in this online program were easy to read.</td>
<td>4.38</td>
</tr>
<tr>
<td>The speech in this online program was synchronized with the sign.</td>
<td>3.80</td>
</tr>
<tr>
<td>It was easy to ‘pause and post’ my ideas on the DeafEd.net bulletin board.</td>
<td>4.43</td>
</tr>
</tbody>
</table>

The lowest ratings related to the synchronization between captions, speech, and sign.

Upon reflection, it was perhaps inappropriate to ask about synchronization of captions/speech with sign. One of the goals in designing the workshop was that the presenter would be using
ASL, while the speech and captions would be in English. As such, determining "synchronization" between two distinct languages is a difficult concept. Nevertheless, the lowest rating indicated the captions were not well synchronized with the speech. Only four participants responded to that item; two others were using Macintosh computers (therefore, no captions) and it is assumed the other two were deaf (therefore, no access to the speech). The ratings ranged between 2 (Disagree) and 4 (Agree), which perhaps indicates a difference in performance on different computers. Again, this is something to investigate for future workshops.

In the open-response section of the survey, several suggestions were made relating to the technical design and format of the workshop. A number of participants noted that the video window was small and not very easy to see, while the area for the slide was much larger; one individual wondered if the two could be traded, giving a larger video of the presenter and smaller slides. While the video was clear enough to understand the signing, it had a slightly choppy quality. This is likely due to the size of the files involved and the limitations of playing the workshop directly off the internet. If the workshop could be downloaded all at once, then played off-line at a later date, perhaps some video quality could be preserved.

This may also resolve one participant's problem: "The video froze a few times and I would have to watch from the start again, this was frustrating." From another user, "I did not like the way the picture looked. It was dark and [I] had to squint." A third user noted it was "a little difficult to watch the signing and look over at the slides." These problems need to be taken into consideration when developing similar workshops in the future. Regarding the third, workshop designers should be mindful that the presenter should pause sufficiently to give viewers a chance to look at each new slide before continuing.
Despite these problems, the participants responded favorably to the general format. They enjoyed having visual input from both the PowerPoint slides (which incorporated illustrative graphics) and the presenter on the video. Likewise, users appreciated having a full range of communication options with signing, voice, and/or captions. Participants also enjoyed being able to control the pace of the lesson, stopping and starting as they pleased.

**Content Considerations**

Participants varied widely in their experience teaching mathematics to deaf students, ranging from no experience to twenty years. The survey did not ask specifically about the participants' mathematical background, so it is uncertain how much training in mathematics they have had. Table 2 summarizes the responses to survey items related to the content of the workshop (1: “Strongly Disagree” 5: “Strongly Agree”).

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>The slides in this online program enhanced my understanding of the presentation.</td>
<td>4.38</td>
</tr>
<tr>
<td>The pace and flow of this lesson was satisfactory.</td>
<td>4.50</td>
</tr>
<tr>
<td>I found this lesson engaging.</td>
<td>4.63</td>
</tr>
<tr>
<td>I found this lesson enjoyable.</td>
<td>4.63</td>
</tr>
<tr>
<td>I found this lesson informative.</td>
<td>4.88</td>
</tr>
<tr>
<td>I think deaf and hard-of-hearing students would benefit from the discovery learning method in mathematics classes.</td>
<td>4.88</td>
</tr>
<tr>
<td>I would like to take other short courses like this to enhance my knowledge/teaching skills.</td>
<td>5.00</td>
</tr>
</tbody>
</table>

These results clearly indicate that the design of the lesson itself was largely satisfactory. The slightly lower rating related to the slides enhancing understanding may be related to the
aforementioned difficulty of looking back and forth between the presenter and the slides, or the slides may indeed benefit from some refinement. Of particular note is the unanimous response to the final item; all eight participants strongly agreed that they would like to take other short courses similar to the present project.

One obstacle that can be faced when attempting to inform teachers of "best practices" is convincing teachers that they may want to try something that is different from the way they were taught. Thus it was gratifying to see the high degree of agreement that the discovery learning method would be beneficial, as well as to see several participants remark that they wish they had been taught mathematics this way. No fewer than five participants indicated that what they liked best about the workshop were the actual examples being presented to illustrate the approach, and one participant suggested including more examples. This should be kept in mind when designing future workshops, to ensure that a sufficient number of usable examples are included.

Some drawbacks were noted related to the nature of an asynchronous presentation. Because the workshop is pre-recorded and available any time, users cannot ask questions if there is something they don’t understand or would like elaborated. Also, the degree of interactivity is limited. Two participants suggested an expansion of the discussion board concept, increasing both posting and responding to the posts of others, creating an online community. Another participant would have preferred to see the examples modeled with students rather than simply presented. This may be feasible for future workshops, but considerations should be made for the size of the viewing window and ensuring that the teacher is clearly visible.

The workshop was designed with mathematics teachers at the secondary level in mind; however, when selecting topics for the three examples, an attempt was made to cover a range of complexity. Therefore, it was expected that some of the content may be challenging for users
who did not have a great deal of background in mathematics. Table 3 summarizes the ratings related to how well the participants felt they understood the mathematical examples, ranging from 1 (Not At All) to 5 (Very Well). The details of each example are available through the workshop’s written transcript (Appendix C) and accompanying slides (Appendix D).

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example #1: Discovering Pi</td>
<td>4.38</td>
</tr>
<tr>
<td>Example #2: Distributive Property</td>
<td>4.25</td>
</tr>
<tr>
<td>Example #3: Pythagorean Theorem</td>
<td>3.75</td>
</tr>
</tbody>
</table>

All ratings were 3 (Neutral) or higher, so it appears that none of the examples were beyond the grasp of the participants, although clearly the example related to the Pythagorean Theorem was the most challenging. This was expected, and the author decided to include the example for precisely that reason. As noted above, some participants indicated they wish they had been taught mathematics in this manner. A future consideration may be to try some workshops where the focus is more on the mathematics, rather than the pedagogy.

In summary, this was a successful and beneficial first attempt at designing an online workshop to disseminate knowledge of best practices to teachers of the future as well as those already in the field. The lessons learned and information gathered in this process should serve well to shape and refine future efforts. If work in this area continues on this path, the expertise of leaders in this field will be much more accessible to teachers, and this can only benefit the education of deaf and hard-of-hearing students.
References


“Discovery Learning in Mathematics” Instructions

Before viewing the workshop, make sure you meet the system requirements, described on the page titled “Viewing Producer 2003 Presentations.”

If you are using a PC, you may also view the workshop with captions, and we ask that you do so in order to offer feedback related to the quality of the captions. You may find that captions appear automatically. If not, instructions for activating captions are given for various versions of Windows Media Player. (See page beginning with “NEW – Windows Media Player 10.”)

If you are hearing, please be sure your sound is turned on so you can offer feedback related to the voice-over.

Viewing the Workshop

Open TWO browser windows. (File --> New Window) One will be used for the workshop. The other will be used for posting responses (see “Pause and Post” below).

The workshop can be found at the following URL:
http://stream.kent.edu/tmcneal/DiscoveryLearning7.htm

Again, be sure to use Internet Explorer (PC/Mac) or Netscape Navigator (PC only).

Even on a fast connection, it can take up to 5 minutes for the workshop to download. Please be patient.

When it’s finished loading, click PLAY to begin the workshop.
Pause and Post

NOTE: During filming, we thought a different software package would be used. Dr. Kurz will describe a "Pause and Post" button that does not exist in the finished product. Instead, use the regular "Pause" button when prompted to Pause and Post.

Go to the other browser window you opened earlier. The discussion bulletin board can be found at:
http://www.rit.edu/~comets/discus/messages/1/1.html
(Yes, there's only one "s" on "discus.")

There's a different section for each time you're asked to Pause and Post a response. Click the link for that topic. Type your message in the window and use the following log-in information:

Username: math
Password: rachel

Everyone will use the same log-in. Do not give any identifying information in your post!

When finished with a response, click "Preview/Post Message." You'll see a preview – if it looks okay, click "Post This Message." You'll see the full thread, including your post. Return to the workshop window and resume viewing.

When you reach the next "Pause and Post" prompt, you can click the link labeled "Next" near the top-right of the window to proceed to the right area on the discussion board.

Feedback Survey

When you have completed the workshop, go to:
http://clipboard.rit.edu/takeSurvey.cfm?id=366376

Follow the instructions and fill in your responses. Some items will not be applicable if you used a Mac or if you are deaf.

Thank you again so much for your participation. Please email me if you have any questions or problems related to these instructions.

Rachel Lewis
mathpro411@hotmail.com
Viewing Producer 2003 Presentations

Presentations created with Producer 2003 can be viewed using computers with these operating systems and software.

Windows Operating System

To view Producer 2003 presentations on a computer running the Windows operating system, you need:

• Windows NT® 4.0 or later, or Windows 98 or later.
• Microsoft Windows Media Player® 6.4 or later.
• Microsoft Internet Explorer 5.0 or later, or Netscape Navigator 7.0 or later.

Notes

• Presentations that contain content based in Windows Media Audio 9 Voice or Windows Media Video 9 Screen require Windows Media Player 7.0 or later.
• Microsoft recommends using Windows Media Player 9 Series to optimize presentation playback.

Apple Macintosh Operation System

To view Producer 2003 presentations on a computer running the Macintosh operating system (OS), you need:

• Apple Mac OS X v 10.2 or later.
• Windows Media Player for Mac OS X.
• Internet Explorer 5.2.2 (or later) for Mac.

Advanced playback features are not available when you view a presentation in Netscape Navigator running on the Windows operating system or in Internet Explorer for the Macintosh. For complete information about presentation playback differences in different browsers, see Producer 2003 Help.
NEW - Windows Media Player 10

Windows media player 10 has the same keyboard shortcut as player version 9. Hold down the $\text{Shift} + \text{Ctrl} + \text{C}$ buttons to quickly turn captions on or off.

To enable captions from the Media Player menu instead, you can choose

Play » Captions and Subtitles » On if available

These options are illustrated in screenshot 3, below. If a file is currently playing, you can select from multiple subtitle languages where provided (see screenshot 4) using

Play » Captions and Subtitles » 'English (or other language) Captions'

In all other respects, Windows Media 10 is the same as Windows Media 9 for captions. Please note that in Windows Media Player 10, you will need to turn off hardware acceleration when viewing captions in full screen mode.
Windows Media Player 9

Windows media player 9 has a quick keyboard shortcut. You can hold down the Shift + Ctrl + C buttons to quickly turn captions on or off. This is called a toggle - press these keys once when you have clicked on the player, and it will turn captions on, do this again to turn them off.

To enable captions from the Media Player menu instead, you can choose

Play » Captions and Subtitles » On if available

These options are illustrated in screenshot 5, below. Player version 9 has the same way of resizing the caption area as Player version 7.
Windows Media Player 7

In our opinion, Microsoft made the selection of subtitles in Media Player 7 far too difficult. There doesn’t appear to be a keyboard shortcut to do this. So, from the Media Player menu, you can choose

View » Now Playing Tools » Captions

1. Now Playing Tools (includes equaliser, captions, visualisations
2. Select Captions. Make sure ‘Show Equalizer and settings’ is also selected
3. Also, make sure ‘Show Resize Bars’ is selected
4. Finally, you can change the size of this area by dragging the resize bars to full lines of captions can be displayed.

Note: You may need to enable resizing of the caption area. This can become locked to a fixed size, and you may find captions don’t fit fully in the box when viewed.

To resize this area, you can drag the thin grey bars up and down to make the area bigger. This is labelled 4 in the screen shot below of Media Player 7.
Windows Media Player 6.4

Older systems, especially windows 98, may still have Windows Media player 6.4 installed. This offers the simplest way of turning on captions!
1. From the Windows Media player menu, choose 'View'.
2. Now, pick 'Captions', and the option will become enabled.

The captions for presentations will appear in the area labelled 3, in Screenshot 5 below.
Evaluation of the Online Discovery Learning Program

Instructions:

This is a short questionnaire to evaluate the experimental project "Discovery Learning." Your evaluation will be helpful as we examine the potential of online learning for Teacher Education programs.

Thanks!

1. I am a ...
   a. Preservice Teacher Education Candidate
   b. Veteran Teacher of the Deaf
   c. College/University Faculty
   d. Other

2. How many years experience do you have teaching deaf/hard-of-hearing students?

3. Number of years experience teaching mathematics to deaf students.

4. I am currently using the following to observe this "Discovery Learning" unit:
   a. PC
   b. Mac

Questions 5-18 are rated on the following scale:
Strongly Disagree—Disagree—Undecided—Agree—Strongly Agree—Not Applicable

5. The signing in this online program was clear.
6. The captions in this online program were easy to read.
7. The captions in this online program were synchronized with the signs.
8. The captions in this online program were synchronized with the speech (If you are deaf, please click "Not Applicable.")
9. The slides in this online program enhanced my understanding of the presentation.
10. The slides in this online program were easy to read.
11. The speech in this online program was synchronized with the sign (If you are deaf, please click "Not Applicable.")
12. It was easy to "pause and post" my ideas on the Deafed.net bulletin board.
13. The pace and flow of this lesson was satisfactory.
14. I found this lesson engaging.
15. I found this lesson enjoyable.
16. I found this lesson informative.
17. I think deaf and hard-of-hearing students would benefit from the discovery learning method in mathematics classes.
18. I would like to take other short courses like this to enhance my knowledge/teaching skills.
Appendix B

Discovery Learning B2

Questions 19-21 are rated on the following scale:
Not At All — (between) — Neutral — (between) — Very Well

I understood:
19. Example 1: Discovering Pi
20. Example 2: Distributive Property
21. Example 3: Pythagorean Theorem

22. What did you like most about this multimedia online lesson?
23. What did you like least about this multimedia online lesson?
24. What other mathematics topics would you like to see offered through this format for teacher education?
25. What other non-math topics would you like to see offered in this format for teacher education?
26. If we develop more lessons like this to prepare teachers in preservice teacher education programs or to update teachers who are already teaching, what improvements do you suggest for such an online program of study?
27. General Comments about this experimental project?
28. Thank you! Please submit your survey.
Hello, my name is Chris Kurz. I teach mathematics and also train future teachers of deaf children.

Teaching mathematics effectively to deaf students, regardless of the school setting – residential, integrated, self-contained, etc. – requires a good understanding of the characteristics of deaf learners as well as the national standards in mathematics established by the National Council of Teachers of Mathematics, or NCTM. Both the research with deaf learners and the general guidelines and recommendations of NCTM point to the need for increased student-centered learning.

There are many issues that teachers face in implementing student-centered learning, including preparation in regard to “best practices,” content knowledge in mathematics, and – in our case – knowing more about the lags deaf students may experience as a result of missed opportunities with parents and other teachers when the children were young.

This lesson will emphasize one type of student-centered learning — what we call “discovery learning.” Like other kinds of active learning, discovery learning involves the student and helps develop thinking skills. The student is actively involved in doing mathematics.

Discovery learning can take different forms, involving varying amounts of guidance by the teacher, but the emphasis is always on this notion of students doing mathematics and constructing their knowledge, rather than passively watching explanations or lectures.

The strategies I emphasize in this lesson are based on both research and discussion with experienced, master teachers in our field. I must stress that this is only an introduction, briefly covering discovery approaches in teaching. At the end of the lesson, I will mention several resources for further information.

Before we continue, please note the Table of Contents to the left of your screen. Below it is a link titled “Pause and Post.” Several times throughout the lesson, I will ask you to click this link and post comments or respond to a question on the integrated message board. Please, feel free to take the time to read what others have posted as well. We hope this will encourage active discussion amongst both those who are viewing this lesson as a class and those who may be viewing it independently.

Let’s try it now. Take a moment to Pause and Post one or two questions you have about discovery learning in mathematics.

Why is student-centered learning – including discovery learning – important?
Findings from research and national assessments have shown that deaf students do not do as well as their hearing peers in mathematics—especially in problem-solving. Research has shown several possible reasons why.

[Slide 6]
First, often deaf students are denied sufficient opportunities to develop thinking skills that are so necessary for success. Such thinking skills include solving problems with more than one dimension (for example, both size and color), understanding cause-and-effect relationships, and metacognition (thinking about their own thinking as they do mathematics). These skills are important for parents and teachers to emphasize as children grow.

Many student-centered strategies provide opportunities to develop these skills. They also allow students—and ourselves as teachers—to gain insight into their true understanding of mathematical concepts and the way they are thinking as they solve problems.

Second, the English language lags many deaf students experience may make it more difficult for them to cope with reading word problems.

Third, most of a deaf student’s experience in mathematics may be limited to “drill-and-practice” problems rather than “true problems.” This is true from K-12. True problems are deeper, richer problems which may not be clearly defined. They may also have more than one answer, or more than one approach to solving.

[Slide 7]
Research has shown that when students are actively, cognitively engaged in activities that are not just “hands-on” but more importantly “minds-on,” they do better in both factual recall and general learning than when they passively watch a lecture. While “hands-on” activities address different learning styles and provide students with a concrete basis for mathematical concepts, “minds-on” activities encourage students to think about core concepts and to ask questions and seek answers that enhance their understanding. Lectures can be effective, particularly when there are many student-centered activities embedded.

The following examples not only focus on the mathematical objectives, but also challenge the student in terms of cognitive and linguistic development. Just like with any other type of learning, practice will certainly help students develop both their skills and knowledge. But I want to be clear about what I mean by “practice.” I do not mean “drill.” By practice I mean giving students plenty of “minds-on” experience with challenging activities, where they discover principles for themselves and take responsibility for their own learning, as well as communicate about their learning with others.

[Slide 8]
Before I begin this example, note that I will sign DIAMETER like this, and CIRCUMFERENCE like this.
In a teacher-centered classroom, students are often told a brief definition of pi, its approximate numerical value (about 3.14), and the formulas for the circumference and area of a circle. They then complete several exercises to find the circumference or area of various circles. I will now present a more student-centered alternative. Let's assume that the students already know the meaning of the terms “diameter” and “circumference,” though not the formula for the latter.

[Slide 10]
Have several circular objects available, or have students bring one or two objects from home, such as these. Encourage students to devise a way of accurately measuring the diameter and circumference of their object. You will want to have rulers and some string available — it’s best to have a type of string that doesn’t stretch much. The diameter is fairly simple to measure by measuring across the widest part of the circle. One way to measure the circumference is by wrapping the string around the circle, marking the length on the string, then laying the string flat to measure with a ruler. Another way is by rolling, as I will demonstrate.

Hold the circular object on a surface, mark the starting point, and rotate it carefully once around along the table top and mark it again. Be careful not to slip! Then measure from beginning to end.

[Slide 11]
If you’ve not yet discussed the importance of measuring carefully, now is a good time for that. How can students increase the accuracy of their measurements? Take a moment to Pause and Post your ideas.

I have found one way to improve results is if students take each measurement three times, then find the average of their measurements.

[Slide 12]
Once the students have finished measuring, have them record their object’s diameter and circumference in a table on the board or overhead projector. Ask them if they notice any relationships. Some will notice that the circumference is always about three times the length of the diameter. Is it exactly three times the length?

[Slide 13]
Most often it will be a bit more than three times. From here, students can determine how much larger the circumference is as compared to the diameter, and the average value should be fairly close to pi, about 3.14, which can then be introduced formally.

[Slide 14]
Now, compare a lecture presenting pi and the related formulas to this “minds-on” activity where students measure and discover pi for themselves. What advantages do you see in this “minds-on” approach? Take a moment to Pause and Post your response.

[Slide 15]
This next example we’re introducing will focus on the distributive property, which I will be signing like this.
Traditionally, students are told the distributive property explicitly \( a(b + c) = ab + ac \) – and then work through several exercises applying it. Instead, let’s see how taking a geometric approach can help students figure out the property and discover it for themselves.

Take a moment to read the problem shown.

As you can see, this problem is left quite open. Students will need to experiment with different possibilities and investigate the relationships between the numbers. Some students will discover the relationship quickly, while others may need some guiding questions from the teacher. After they work with the example, they’ll find that the Area of the Smaller Room + the Area of the Larger Room = the Area of the Original Room.

This is the case no matter how they change the dimensions. Two possibilities are shown on the slide. Encourage them to write a mathematical statement to show the equality, such as \( 6(4) + 6(7) = 6(11) \). Now they will also likely see that they can add the 4 and the 7 to get 11, which can then be multiplied by 6. This can be written symbolically as \( 6(4 + 7) \).

As students saw, it didn’t matter what two numbers they separated 11 into – 4 and 7, 2 and 9, 6 and 5 – the same relationship held. So challenge them to write this relationship as a rule that doesn’t depend on specific numbers. Now they will come up with a formula equivalent to \( a(b + c) = ab + ac \), and the formal name of the property can be presented and discussed.

What are your thoughts on using this approach to teach the distributive property? Take a moment to Pause and Post your response.

One key to discovery learning is that the concept to be discovered must be just within the students’ reach. In other words, they need to be able to make the leap to the new idea using knowledge they already have and what they gather from activities. This often means some building blocks need to be established before you reach the final goal. We’ll see this in the final example on the Pythagorean Theorem, which I will sign “Pythagorean Theorem”.

Prior to this lesson, students would already have learned about finding areas of squares drawn on grids. Regardless of whether the squares sit ‘flat’ or are ‘tilted’, students will have ways of figuring out the areas – they may count squares, they may multiply the side lengths, or they may divide the shape into smaller pieces. They would also know the relationship between that area and the length of the side of the square – namely, that the square root of the area gives the length of the side.
Appendix C

To begin this activity, each student should pick two numbers, both between 1 and 6. They can be the same, like 3 and 3, or different, like 1 and 5. They should note down the numbers they chose on the corner of a piece of dot grid paper.

[Slide 23]
Now, they should draw a right triangle on the grid paper using their two numbers as the lengths of the legs. The figure here shows what it would look like if you chose the numbers 2 and 3. How can we find the length of the tilted line, or hypotenuse? Allow students to use whatever method they like, but be sure it's valid.

[Slide 24]
One way is by using their knowledge of squares. The example shown has a square with an area of 13 square units. You can see that the square’s been divided into four right triangles which add up to 12 square units, and then a single unit square in the middle which makes an area of 13 square units. So the original line has a length of $\sqrt{13}$ units.

[Slide 25]
Make a table of all the examples in the class, showing the two numbers chosen and the length of the tilted line. You may have values such as those shown here. Ask students to look for a way to use the first two numbers to come up with the line length. Try making it more fun for them by telling them there’s a secret relationship between the numbers — make it more of a puzzle than a math problem. Give them some time to play with the numbers. They may want to create more examples for a longer table.

[Slide 26]
Now is a time for flexibility. Some students will be able to find a rule on their own, while others will need a little guiding. If they don’t see the pattern on their own, try asking if they can use squares to find the other two lengths of the triangle, just as they did to find the length of the tilted line. This will lead to something like the picture shown here, with squares drawn on the legs of the right triangle, and students can see that the areas of the two smaller squares together equal the area of the larger square. This can now be written symbolically, and the formal name of the Pythagorean Theorem can be introduced along with the formula $a^2 + b^2 = c^2$.

Often, our textbooks directly provide explanations of concepts and formulas. When students read the book first, the opportunity to discover a principle or concept may be lost. We need to do everything we can to keep the thrill of discovery alive in our courses. Imagine how different this lesson would have been if some students saw the formula $a^2 + b^2 = c^2$ beforehand.

[Slide 27]
Discuss your thoughts on approaching the Pythagorean Theorem in this way. Would you do it differently? If so, explain how you would approach the Pythagorean Theorem. Take a moment to Pause and Post your response.

[Slide 28]
In these few examples, we have seen ways of having students involved in the lesson with their "minds on" by helping them discover mathematical principles. Again, research tells us that the more a student is cognitively engaged, the more he or she will truly learn.

[Slide 29]
In summary, as teachers we need to set ourselves some broad goals when teaching mathematics to deaf students. This lesson focused on only one aspect of student-centered instruction — discovery learning. We will be doing our students a great service by: First, examining our courses and deciding when discovery learning would be appropriate; second, deciding how to structure discovery within our lessons (such as planning our prompts, our guiding questions, and so on); third, identify ways we can excite our students to want to discover principles, ask questions, and become independent learners.

[Slide 30]
Discovery learning and other forms of student-centered learning can be carried out in any area of mathematics, from elementary school basics to high school courses. The secret is to plan the activities carefully so that they are both fun and help the student to want to discover new things. We do not want the student to be dependent on being told what to do, so we must gauge our prompts and guidance to give just enough for him or her to move ahead on their own. Through experience with discovering mathematical principles and concepts, and through having dialogue with peers and the teacher, students will have much better understanding and preparation for higher-level courses.

[Slide 31]
For activities on a particular topic, the easiest place to start is on the internet. Simply go to a search engine and type a phrase such as "math activity" and "discovery" along with a keyword such as "circle" or "slope" or "probability." Many activities can be found; select those which will help students discover principles on their own. Also, many books and resources are available through NCTM and other publishers.

Many of us grew up with mathematics teachers who told and showed us the information and procedures, which we were expected to absorb and duplicate. Since that style is so familiar, it can be understandably comfortable to teach that way, but I encourage you to try more effective approaches — research show the results will be worth it.

I hope that after this brief introduction to discovery learning, you will learn more about student-centered instruction and begin to try it in your own teaching experiences.
Discovery Learning in Mathematics

Key Strategies for Deaf Learners

Teacher Needs

- Learn about “best practices”
- Gain content knowledge in mathematics
- Understand the lags particular to some deaf learners
Discovery Learning

- Key Ideas:
  - Students *DOING* mathematics
  - Students constructing knowledge
  - *NOT* passively watching lecture

Pause & Post

Share one or two questions you have about discovery learning in mathematics.
Rationale

- Deaf students are often behind their hearing peers in mathematics

- Why?

Some Possible Reasons

- Not enough opportunities to develop thinking skills

- English language lags

- Prevalence of "drill-and-practice" exercises
Beyond "Hands-On"

**"Hands-on" activities:**
- Different learning styles
- Concrete foundation for concepts

**"Minds-on" activities:**
- Think about concepts
- Ask questions
  - Find answers

Example #1:
Discovering Pi
Discovering Pi

- Materials:
  - Circular objects
  - Rulers, metersticks, tape measures, etc.
  - String
Pause & Post

How can students increase the accuracy of their measurements?

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Circumference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2 cm</td>
<td>16.8 cm</td>
</tr>
<tr>
<td>11 cm</td>
<td>34.1 cm</td>
</tr>
<tr>
<td>27.5 cm</td>
<td>81 cm</td>
</tr>
<tr>
<td>15.8 cm</td>
<td>48.2 cm</td>
</tr>
</tbody>
</table>
### Slide 13

<table>
<thead>
<tr>
<th>Diameter (cm)</th>
<th>Circumference (cm)</th>
<th>( C/d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2</td>
<td>16.8</td>
<td>( \approx 3.31 )</td>
</tr>
<tr>
<td>11</td>
<td>34.1</td>
<td>( \approx 3.10 )</td>
</tr>
<tr>
<td>27.5</td>
<td>81</td>
<td>( \approx 2.95 )</td>
</tr>
<tr>
<td>15.8</td>
<td>48.2</td>
<td>( \approx 3.05 )</td>
</tr>
</tbody>
</table>

*Average*: \( 3.10 \)

---

### Pause & Post

What advantages do you see in this "minds-on" approach over a lecture where students are told the definition and shown how to use the formula?
Example #2:
The Distributive Property

\[ a(b + c) = ab + ac \]
Avery wants to remodel his rectangular living room, 11 meters long by 6 meters wide, and transform it into two rooms by adding one wall. He wants one room to be larger than the other.

Find possible dimensions and areas of: a) the original room, b) the larger new room, and c) the smaller new room. What relationships do you see between the measures of the three rooms? If Avery decided to change the dimensions of his two new rooms, would it affect the relationships?

\[ 42 \text{ m}^2 + 24 \text{ m}^2 = 66 \text{ m}^2 \]

\[ 36 \text{ m}^2 + 30 \text{ m}^2 = 66 \text{ m}^2 \]
What are your thoughts on using this approach to teach the distributive property?
Example #3:
The Pythagorean Theorem

Prior Knowledge

Area = 9 sq. units
Side length = √9 or 3 units

Area:
4(1.5) + 4 = 10 sq. units
Side length = √10 units
Draw a Right Triangle

Find the Length of the Hypotenuse

Side Length = $\sqrt{13}$ units

Area = 13 sq. units

$2 \times 3 = 6$ sq. units

$2 \times 3 = 6$ sq. units

$2 \times 3 = 1$ sq. unit
## Make a Table of Values

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Line Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>$\sqrt{2}$</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>$\sqrt{13}$</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>$\sqrt{10}$</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>$\sqrt{8}$</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5 (or $\sqrt{25}$)</td>
</tr>
</tbody>
</table>

## The Visual Relationship

$4 + 9 = 13$

$$(2)^2 + (3)^2 = (\sqrt{13})^2$$

Leg #1 = $a$

Leg #2 = $b$

Hypotenuse = $c$

$$a^2 + b^2 = c^2$$

The Pythagorean Theorem
Discuss your thoughts on teaching the Pythagorean Theorem in this way. Would you do it differently? If so, explain how you would approach the Pythagorean Theorem.

↑ Cognitive Engagement = ↑ Student Learning
Teacher Goals

- Find appropriate opportunities for discovery learning
- Determine how to structure discovery in lessons
- Identify ways to motivate students

Keys to Remember

- Discovery learning useful throughout mathematics curriculum
- Make it fun and motivating for students
- Give *just enough* guidance
Find Ideas/Resources:
Internet search

"math activity" discovery probability

Results in: ○ Any Language ○ English

or

NCTM
NATIONAL COUNCIL OF
TEACHERS OF MATHEMATICS