The Role of Multimedia in Intelligent Tutoring Systems

An Interactive Qualifying Project

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in

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by

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APPROVED:

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Abstract

There are numerous examples suggesting that multimedia can be used to enhance e-learning. However, creating multimedia content can be time-consuming and/or expensive, which is why we chose to study the effect of multimedia in the Assistment project (a web-based system that both assists students' learning and assesses their abilities in order to help them prepare for the Massachusetts Comprehensive Assessment System (MCAS) Math test). We performed a randomized controlled experiment where 50% of the students were assigned (after a pre-test) to a condition with multimedia content, while the other 50% of students received the already existing content that did not have multimedia. While the results showed that there was no statistically significant difference between the two groups, this study discusses several possible reasons for that and proposes a number of areas of study and testing that would clarify and build on this work.

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Chapter I

Introduction

Providing relevant graphic images in addition to text is one of the methods used to engage students in active learning. Graphic images can be used to illustrate specific content types, to show relationships among topics in a lesson, and also as an interface to the presentation of educational material. According to the cognitive theory in which learning is seen as an active process, it is not sufficient to deliver information to the learner, what is even more important is to enable and encourage learners to actively process the information. An important part of active processing is to mentally construct pictorial and verbal representations of the material and to mentally connect them. (Clark and Meyer, 2003)

In this paper I will discuss the impact of using multimedia in the Assistment project. This is a web-based system designed for 8th graders preparing for the MCAS Math test. MCAS stands for The Massachusetts Comprehensive Assessment System. It is a set of tests used to measure performance based on the learning standards in the Massachusetts Curriculum Frameworks in the following areas: Reading/English/Language Arts, Mathematics, History/Social Science and Science/Technology/Engineering. MCAS results are used mainly for evaluation purposes; Massachusetts public school students must pass both the English/Language Arts and the Mathematics sections of the MCAS in order to graduate from high school.

Chapter II provides a brief review of the literature on multimedia learning, and discusses some techniques used to make multimedia more effective.

Chapter III presents the Assistment project and gives an example of an actual Assistment item that was used in the experiment.

Chapter IV contains examples of 3 pairs of multimedia and no-multimedia items, involving three mathematical skills – equation solving, Venn diagrams, and area and perimeter of a polygon.

Chapter V describes the experiment – method (subject, design, materials and apparatus) and the results of the experiment.

Chapter VI is the conclusion.

The screen shots of the Assistments built for the experiment can be found in Appendix A.

Chapter II

Literature Review

Several researchers have already addressed the problem of using multimedia for enhancing e-learning. In this chapter I will present an analysis of some works in this field (see Bibliography for a complete list of references). While some studies show that multimedia does not help students' learning, many suggest that it does. However, the effect of multimedia depends on whether an appropriate type of multimedia was used in each situation.

According to Michael Simkins (Simkins, 2002), the five types of multimedia elements (objects) are:

1. *Images*. Images come in many forms. A few notable types include graphs, maps, photographs, and drawings.
2. *Text*. This includes everything from image captions to paragraphs of information.
3. *Sound*. A few examples are voice recordings, music, and sound effects. Sounds can be used alone or to enhance another media element.
4. *Motion*. This includes cartoon-type animation, video, and moving transitions between screens of media.
5. *Interactivity*. This includes making buttons, hyperlinks, and the like.

While the use of sound is often limited in a regular classroom setting unless headphones are employed, the Assistment project involved the other four types extensively. When presenting graphic images, we used *explanative*, rather than *decorative,* illustrations, which provides for a greater increase in students' learning (Clark and Meyer, 2003). When I designed my multimedia Assistments, I tried to make appropriate use of the following principles (Faraday and Sutcliffe, 1997):

- Use words to reinforce an image (including captions and labels),
- Reveal information systematically to control attention,
- Avoid animation or reveal motion during the moment of time when a label is being mentioned, and
- Use animation to show more than just the initiation of an action; use it to show the result as well.

Providing more interactivity in user interfaces is believed to have a substantial positive effect on learning. Interactive interfaces

- Allow students to control, manipulate and explore material (an example would be the use of "hints" which I will talk about later), or
- Allow the system to periodically ask students questions that help them to integrate the material (which was implemented by the use of scaffold questions).

Interaction may be useful because it encourages learners to invest more in the process of learning. For this to occur, the interaction must be cognitively engaging (i.e., not merely selecting hyperlinks). (Faraday and Sutcliffe, 1997)

In the next chapter we will take a closer look at the Assistment project and see how what I have presented so far is used in a practical application with actual students.

Chapter III

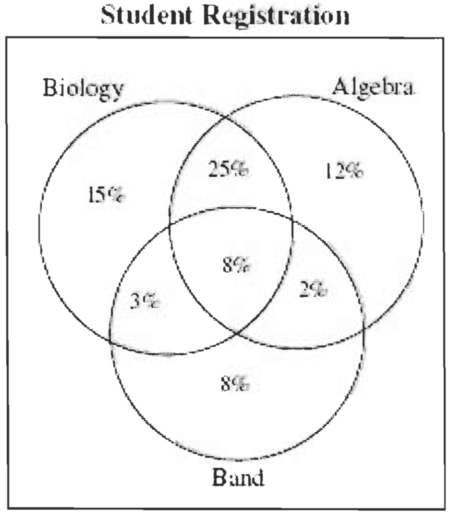
The Assistment Project

The term "Assistment" was coined by Kenneth Koedinger (Human-Computer Interaction Institute, Carnegie Mellon University) and blends Assessment and Assisting. What makes the Assistment Project stand out from the rest of similar projects is that it combines assisting students' development and assessing students' abilities (which is normally hard to accomplish because of limited classroom time availability).

Figure 2.1 shows a problem that appeared on an MCAS Math test for the 8^{th} grade.

At student registration, eighth-grade students selected the courses they would be taking next year as ninth graders. The counselor made the diagram below that shows a relationship among the percentages of students who chose to take Biology, Algebra, and/or Band.

Student Registration

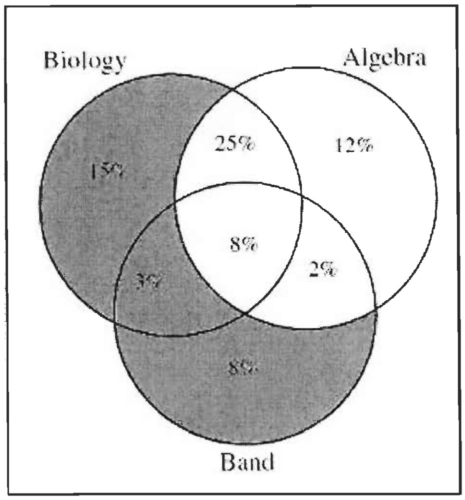


If 900 students signed up to take courses, how many will not be taking Biology, Algebra or Band? Show or explain your work.

Figure 2.1

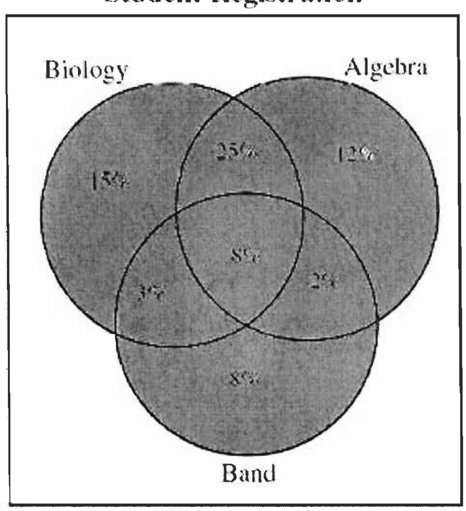
Figure 2.2 shows an Assistment built for the question above. Each Assistment consists of an *original item* and a list of *scaffolding questions*. The first scaffolding question appears only if the student gets the item wrong or asks for a "hint". Figure 2.2 shows that the student typed "23", which turned out to be a wrong answer. After students make an error, they are not allowed to try the item further, but instead must then answer a sequence of scaffolding questions (or "scaffolds") presented one at a time. Students work though the scaffolding questions, until they eventually get the problem correct (the last scaffold usually takes the student back to the original problem). If the student presses the hint button while on the first scaffold, the first hint is displayed, which shows the percentage of students taking Biology, but not Algebra or Band in this example. If the student hits the hint button again, the next hint appears which shows the percentage of students taking Biology and/or Band, but not Algebra. The student may or may not go through all the hints before answering the scaffolding question. Once the student gets the first scaffolding question correct (in this case that would be "73"), the second scaffolding question appears.

Student Registration



Now we added the percentage of students taking Biology and/or Band, but not Algebra.

Student Registration



Now you see that in order to find the total percentage of people taking Biology, Algebra or Band you need to sum up all the percentages shown on the diagram.

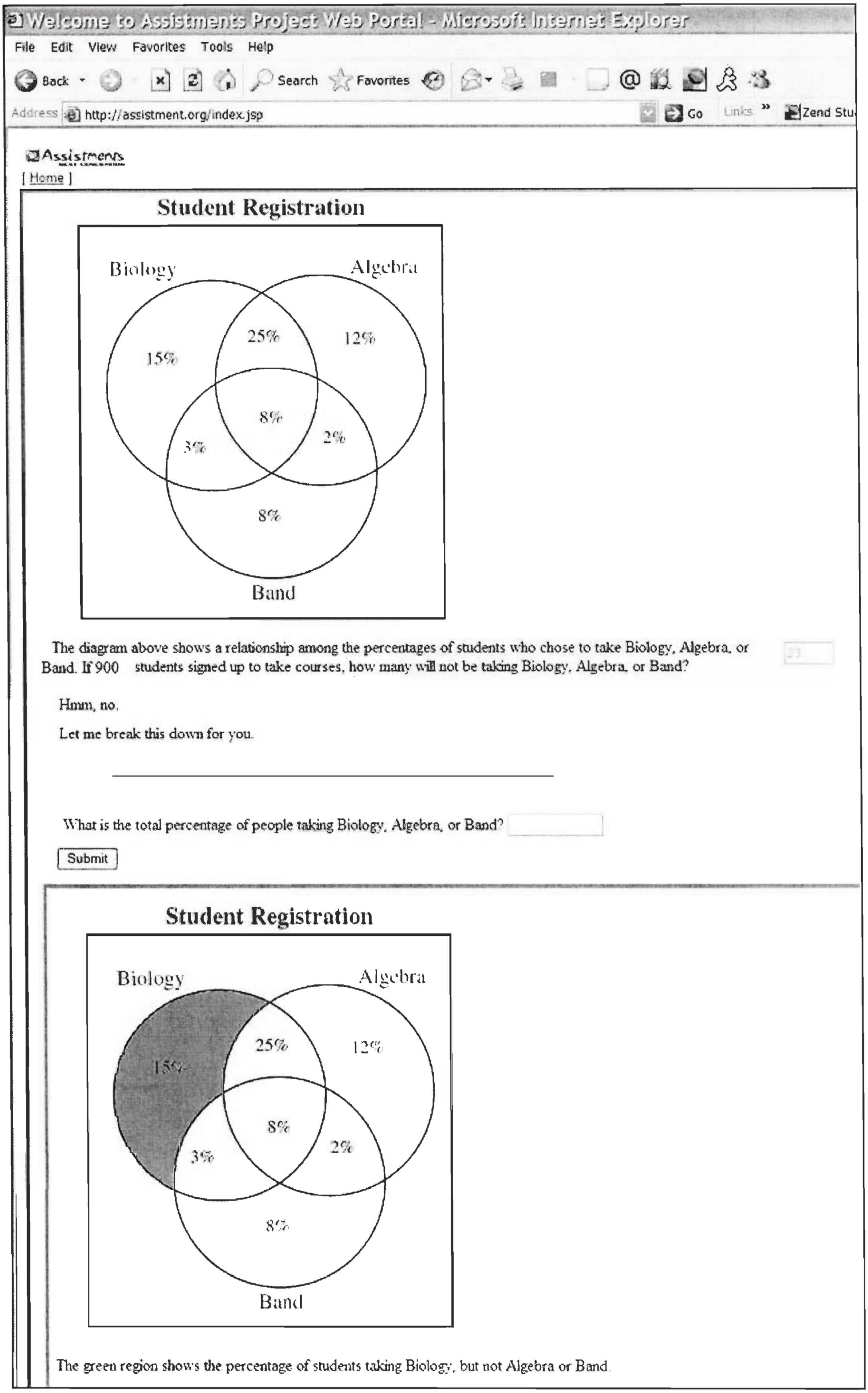
What is 15 + 25 + 8 + 2 + 3 + 12 + 8?

The answer is 73%. Type in 73.

Done Hint More

Done

Figure 2.2


Welcome to Assistments Project Web Portal - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://assistment.org/index.jsp
Go Links Zend Stu
Assistments
[Home]
Student Registration
Biology
Algebra
15%
25%
12%
8%
3%
2%
8%
Band
The diagram above shows a relationship among the percentages of students who chose to take Biology, Algebra, or Band. If 900 students signed up to take courses, how many will not be taking Biology, Algebra, or Band?
23
Hmm, no.
Let me break this down for you.
What is the total percentage of people taking Biology, Algebra, or Band?
Submit
Student Registration
Biology
Algebra
15%
25%
12%
8%
3%
2%
8%
Band
The green region shows the percentage of students taking Biology, but not Algebra or Band.

Chapter IV

Comparison of the multimedia vs. no-multimedia items

First we are going to look at the item assessing equation solving. Below is a screen shot of the item that does not contain multimedia (the hint messages will be shown on the multimedia item – the content of the two is identical except for the fact that one of them contains graphics and the other does not):

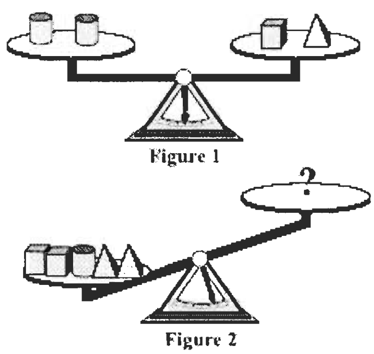


Figure 4.1

How many **cylinders** must be placed on the empty side of the second scale to make that scale balance?

A. 5
B. 2
C. 4
D. 3

Let me break this down for you.

First, look at the first scale and check what are the two cylinders equal to in terms of cubes and pyramids?

a cube and a pyramid
a pyramid
two cubes
two pyramids and a cube

Now take a look at the second scale. How many **cube + pyramid** pairs are there on the left side of the scale? 2

How many **cylinders** is that equal to? 4

There is **one more object** on the left side of the second scale. With that in mind, how many cylinders must be placed on the empty side of the second scale to make that scale balance? 5

As we can see, the only graphics in the item above is the figure in the original question. Here’s that same item but with a picture for each scaffold question (most of the pictures were animated, which could not be shown in this paper):

Figure 4.2

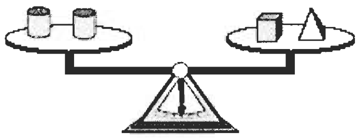


Figure 1

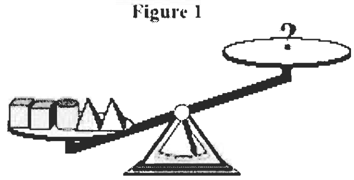


Figure 2

How many **cylinders** must be placed on the empty side of the second scale to make that scale balance?

A. 5

B. 2

C. 4

D. 3

Let me break this down for you.

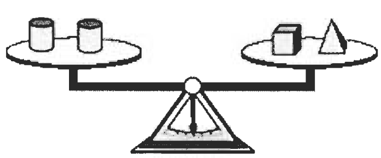


Figure 1

First, look at the first scale and check what are the two cylinders equal to in terms of cubes and pyramids?

a cube and a pyramid

a pyramid

two cubes

two pyramids and a cube

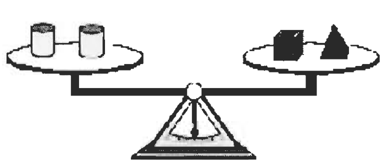
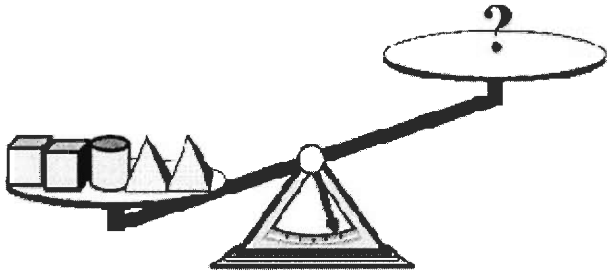


Figure 1

Look at the right side of the first scale.

The answer is a cube and a pyramid

Done | Hint | More



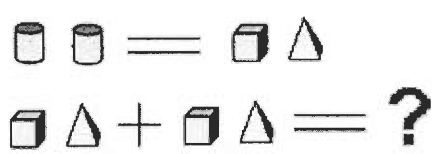
Now take a look at the second scale. How many **cube + pyramid** pairs are there on the left side of the scale? 2

Count the number of cubes and the number of pyramids on the scale.

There are two cubes and two pyramids.

Type 2 for the answer and press Submit.

Done Hint More



How many **cylinders** is that equal to? 4

Use the balance scales below to answer question 4.

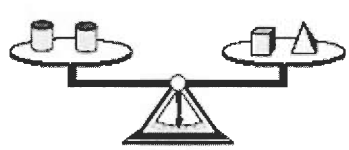


Figure 1

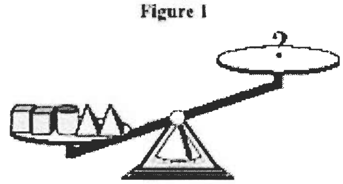


Figure 2

There is **one more object** on the left side of the second scale. With that in mind, how many cylinders must be placed on the empty side of the second scale to make that scale balance? 5

The second item seems to be a lot more explanatory than the first one.

Another example we are going to look at involves Venn diagrams. While the multimedia item has already been shown in the previous chapter, here's that same item without graphics:

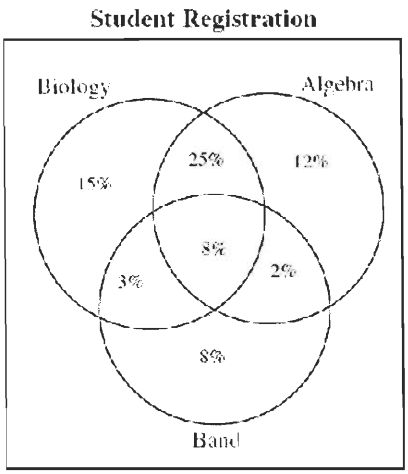


Figure 4.3

The diagram above shows a relationship among the percentages of students who chose to take Biology, Algebra, or Band. If 900 students signed up to take courses, how many will not be taking Biology, Algebra, or Band?

Let me break this down for you.

What is the total percentage of people taking Biology, Algebra, or Band? 73

In order to find it, sum up all the percentages shown on the diagram.

What is 15 + 25 + 8 + 2 + 3 + 12 + 8?

The answer is 73%. Type in 73.

Done | Hint | More

Correct. Now you need to find out the percentage of students who did **NOT** sign up for Biology, Algebra or band. 27

The total percent of students is 100%. The percent of students taking Biology, Algebra or band is 73%. What is the percentage of students not taking Biology, Algebra or band?

What is 100-73?
Type in 27.

Done | Hint | More

Right. Now you can find the number of students who will **NOT** be taking Biology, algebra or band. The total number of students is 900. what is 27% of 900? 243

Turn 27% into a decimal and multiply by 900.

27% is 0.27 in decimal.

What is 900*0.27?

900*0.27=243. Type in 243

Done | Hint | More

The last pair of items deals with a perimeter and an area of a polygon:

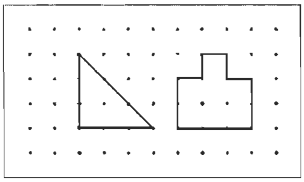


Figure 4.4

Which statement is true about the two polygons?

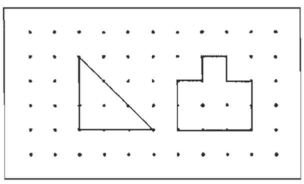
A. They have equal areas but different perimeters.

B. They have equal perimeters but different areas.

C. They have equal areas and equal perimeters.

D. They have different areas and different perimeters.

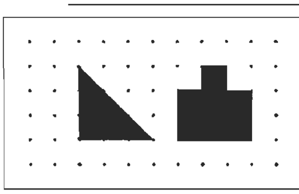
Let me break this down for you.



First, let's start with comparing the two polygons' perimeters. Perimeter is the sum of the lengths of all the sides of a polygon. Which polygon has a greater perimeter?

Look at the picture above, where the perimeter of each polygon is outlined in red.
Let's say that the distance from one point to another is equal to 1 unit. Then the distance of the diagonal from one point to another will be approximately 1.5 untis. With that in mind, compute the perimeter of each polygon and compare the two values.
Perimeter of the left polygon is approximately equal to 10 units, while perimeter of the right polygon is equal to 12 units.

Done Hint More



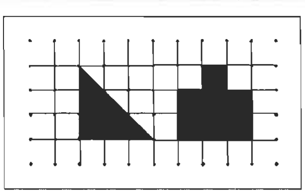
We've just eliminated two choices - B and C. Now let's take a look at the areas.
Look at the picture above (each red area represents the area of the polygon). Which polygon has a greater area?

○ both have the same area

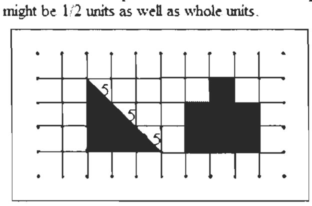
○ the one on the left

○ the one on the right

Submit



Take a look at this picture. Assume each small square's area is equal to one square unit. Keep in mind that there might be 1/2 units as well as whole units.



Compute the area for each polygon from the image below and compare the two values.
The area of the left polygon is equal to 4.5 square units, while the area of the right polygon is equal to 7 square units.
Thus, the answer is **the one on the right**.

Done Hint More

The matching no-multimedia item is shown below:

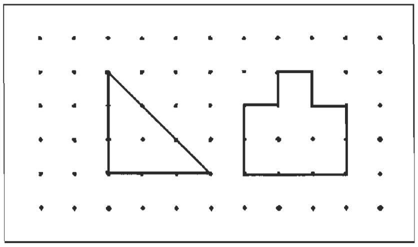


Figure 4.5

Which statement is true about the two polygons?

A. They have equal areas but different perimeters.

B. They have equal perimeters but different areas.

C. They have equal areas and equal perimeters.

D. They have different areas and different perimeters.

Let me break this down for you.

First, let's start with comparing the two polygons' perimeters. Perimeter is the sum of the lengths of all the sides of a polygon. Which polygon has a greater perimeter?

Let's say that the distance from one point to another is equal to 1 unit. Then the distance of the diagonal from one point to another will be approximately 1.5 untis. With that in mind, compute the perimeter of each polygon and compare the two values.
Perimeter of the left polygon is approximately equal to 10 units, while perimeter of the right polygon is equal to 12 units.

Done Hint More

We've just eliminated two choices - B and C. Now let's take a look at the areas.
Look at the picture above (each red area represents the area of the polygon). Which polygon has a greater area?

○ both have the same area

○ the one on the left

○ the one on the right

Submit

Assume each small square's area is equal to one square unit. Keep in mind that there might be 1/2 units as well as whole units.
Compute the area for each polygon and compare the two values.
The area of the left polygon is equal to 4.5 square units, while the area of the right polygon is equal to 7 square units.
Thus, the answer is **the one on the right**.

Chapter V

The Experiment

Method

Subjects and design

The subjects were 8th grade students attending the Forest Grove Middle School in Worcester, MA. For the purpose of the experiment, they were randomly divided into two approximately equal groups: one group got multimedia Assistments, and the other one got non-multimedia Assistments.

Materials and apparatus

I created a curriculum, which consisted of three parts – the pre-test part, the experimental part (which in turn consisted of multimedia and no-multimedia parts), and transfer items (that is, a post-test). The pre-test part of the curriculum consisted of 2 assistments assessing/teaching the following skills: equation solving and Venn Diagrams. The experimental part was divided into two sub-parts. Part A was 2 multimedia items, testing the two skills above. Part B was 2 non-multimedia items (otherwise very similar to the multimedia ones). Post-test part of the curriculum was 2 transfer items, testing the same skills.

Procedure

From now on, I will be referring to the group of students that got multimedia assistments as Group I, while the other group will be referred to as Group II.

Both Groups I and II got the same pre-test items. Then, Group I got Part A of the experimental curriculum, while Group II got Part B (see above for the description of these parts). After that, both groups got the same post-test items.

In both cases, students were tested individually, and not allowed to cooperate with each other. They were, however, allowed to ask instructors for help if they had trouble understanding a particular question or using the Assistment web site.

Results and Discussion

Pre to post test performance

The goal of this study was to determine whether students would show improved results from pre- to post-test, and whether students in Group I would show greater improvement than students in Group II.

While there was a total of 859 students who participated in the experiment, only 615 finished it. Also, we had to exclude all the students who seemed to have weird log messages, probably indicating a bug in the assistment logging system (we made an assumption that this would impact the two conditions equally). After that we had to exclude 75 students who did not participate in the experiment (that is, they got both of the experimental items right and were not affected by the condition). This left us with 489 students for analysis.

The table below indicates the averages for each item:

0.666667	base.RandomSection-0.Scales_2001_15
0.496933	base.RandomSection-0.2004_9_gr8
0.5818	AveragePretest
0.477733	base.RandomSection-1.Multi Media exp 2000-4original with MM
0.093117	base.RandomSection-1.Multi Media exp 2003-9Doriginal with MM (nested scaffolding)
0.466942	base.RandomSection-2.Multi Media exp 2000-4original without MM
0.061983	base.RandomSection-2.Multi Media exp 2003-9Doriginal without MM
0.275051	ExpermentalSectionAverage
0.619632	base.RandomSection-3.Multi Media morph exp 2000-4
0.202454	tbase.RandomSection-3.Problem 30 - 2002
0.411043	PostEverage

It seems like the post test was much harder than the pre test (especially the Venn diagram item).

We also did a test to see if the pretest results were balanced for the two conditions:

Data	MM	noMM	Grand Total
Average of AveragePretest	0.603238866	0.559917355	0.581799591

We conclude that since the difference on the pretest is about 4%, it is statistically significant. Our next step is calculating a gain score per student and performing a t-test by condition.

Unpaired t-test for GainScore
Grouping Variable: Condtion
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
MM, noMM	.006	487	.146	.8842

Group Info for GainScore
Grouping Variable: Condtion

	Count	Mean	Variance	Std. Dev.	Std. Err
MM	247	-.168	.180	.424	.027
noMM	242	-.174	.173	.416	.027

The Experiment Group gain score was about 1% different than that of the Control Group, but we conclude that this difference is not statistically significant.

Chapter VI

Conclusion

The goal of the study was to conduct an evaluation of the use of multimedia in the Assistment project. The data turned out to be statistically inconclusive. While the results seem to indicate that multimedia Assistments could lower scores, the actual number of students with lower scores was quite low. Probable reasons for the decline in scores are the limitation of the study to just four mathematical skills and, perhaps more importantly, the fact that a number of students did not get to go through the scaffolding and the hints that contained multimedia. Another possible reason is that perhaps students would have a greater difference in learning if given more items testing the same skill.

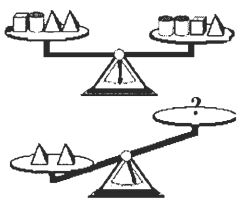
The surprising result was that the post-test results showed that there actually was a *decrease* in learning. The most probable reason for this is that the transfer items were chosen to be harder than the pre-test items (in order to better determine the increase in students' learning), and, as it turned out, the students did not learn enough from just one experimental item.

Overall, I believe that there can be done future work in this field, which could make use of this study's outcome. This study seems to indicate that multimedia when used sparingly may not differ greatly from the use of Assistments without multimedia. Given the nature of multimedia and memory, perhaps multimedia when used consistently over a larger period of time, might through repetition, engage the students' and result in higher scores. Another possible avenue for research would be a comparison of multimedia structured as a game or a challenge with multimedia that was obviously structured for learning such as the ones that were created for this study. Our research indicates the difficulty in making large changes in test results either with multimedia or non-multimedia Assistments with short term reinforcement. Still, we saw that approximately 10% of the students improved their scores after working through an Assistment and in many school systems that type of increase would be very significant so this type of learning system may function as one tool in a wide variety of tools that reinforce classroom learning and through an analysis of the students that did improve, we might be able to tailor specific tools in a student appropriate manner.

Appendix A

Assistment items built for the experiment

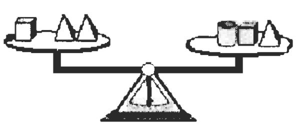
Year 1999, item 33 (morph)



How many cylinders must be placed on the empty side of the second scale to make that scale balance?

Let me break this down for you.

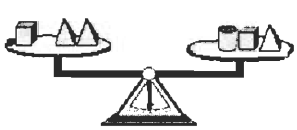
Let me break this down for you.



Let's consider the first scale (the upper one). What happens if we remove, say, a cylinder from the right side of the scale and also one cylinder from the left side?

the scale is still balanced

the scale isn't balanced anymore



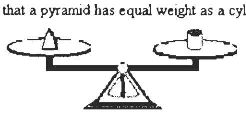
There are some more figures on the first scale that can be cancelled out (removed from both sides). What are they? . Note: each figure should only be mentioned once - say if you remove a cube from both sides, you should select "a cube" as opposed to "two cubes").

a cube and a cylinder

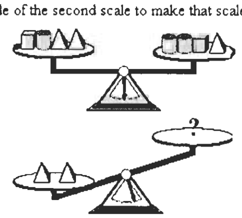
a cube and a pyramid

a cylinder and a pyramid

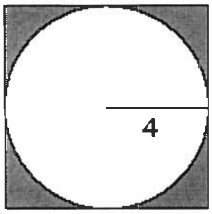
Now that we've removed a cube and a pyramid from both sides, we can see that a pyramid has equal weight as a cylinder.



Let's get back to the original question. How many cylinders must be placed on the empty side of the second scale to make that scale balance?

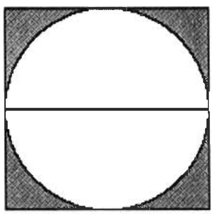


Year 2000, item 25 (morph)



What is the area of the shaded region in the figure above? (Use 3.14 for Pi.)

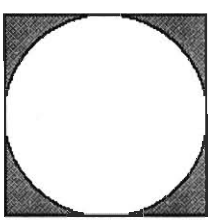
Let me break this down for you.



In order to find the area of the shaded region, you need to subtract the area of the circle from the area of the square. First, lets find the area of the square. What is one side of the square equal to?

○ 16
○ 4
○ 8

Submit



Find the area of the square.

Submit

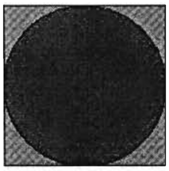
In order to find the area of the square, take the length of one side and multiply it by itself.

The length of one side of the square is equal to 8.

What is 8*8?

The area is 64 sq.units. Type in 64 for answer and click on the Submit button.

Done Hint More



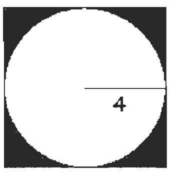
Now find the area of the circle. 50.24

Submit

Area = R*R*Pi, where R is the radius. Use 3.14 for Pi.

Type 50.24

Done Hint More



Okay, now in order to find the area of the shaded region, you need to subtract the area of the circle from that of the square.

What is this number equal to? Submit

The area of the square is 64. The area of the circle is 50.24. What is the area of the square minus the area of the circle?

What is 64-50.24?

Type 13.76

Done Hint More

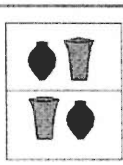
Year 2001, item 28 (morph)

In how many ways can 5 different vases be arranged on a shelf?

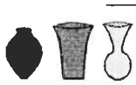
Let me break this down for you.

Let's break the problem in smaller parts. In how many ways can 2 different vases be arranged on a shelf?

Submit



Type in 2.



Let's use 3 vases this time: red, orange, and yellow. First, let's find the number of possibilities for the 1st vase, and then multiply it by the number of possibilities to arrange the rest of the vases.

How many possibilities for the 1st vase on a shelf are there?

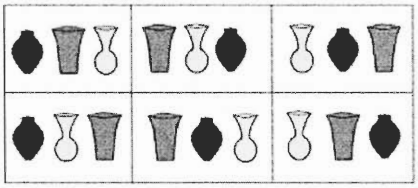
Submit

Since there's a total of three vases, there are 3 possibilities for the 1st vase. It can be either red, orange, or yellow.

Type 3

When we place one of the vases on the shelf, we only have 2 left. We already found the number of ways to arrange 2 vases on ashelf. Now multiply that number by 3 to compute the number of ways to arrange 3 vases.

Submit



Multiply 2 by 3 and compare the number you got to the number you get from the picture below.

Type 6

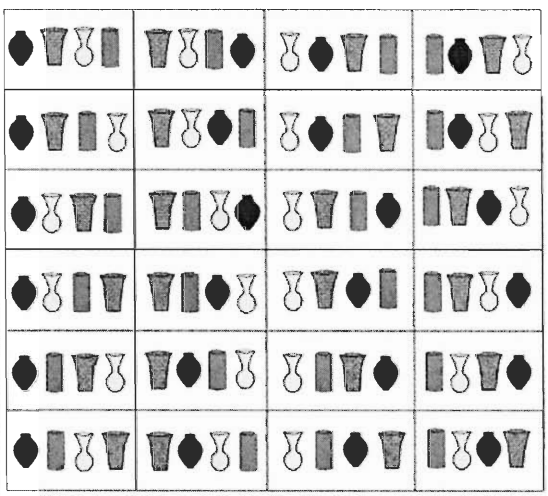
Now try to use the same argument for 4 vases. In how many ways can 4 vases be arranged on a shelf?

Submit

There are 4 possibilities for the 1st vase.

There are 6 ways to arrange the remaining 3 vases.

Multiply 6 by 4 and see if the number you get matches the picture below.



Type 24

No. of Vases	No. of Ways to arrange them
2	2 * 1 = 2
3	3 * 2 * 1 = 6
4	4 * 3 * 2 * 1 = 24
5	?

Look at the table above. Can you tell in how many ways can 5 vases be arranged?

Submit

3 vases can be arranged in 3*2*1 = 6 ways. Similarly 4 vases can be aranged in 4*3*2*1 = 24 ways.
Try to figure out what the pattern is.
5 vases can be arranged in 5*4*3*2*1 ways.
5*4*3*2*1 = 120. Type 120 and press the Submit button.

Year 2001, item 9 (original)

25% of what number is 100? [ ]

Let me break this down for you.

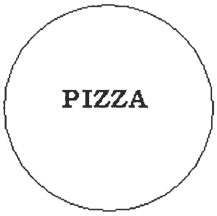
First of all, let's try this: do you think the number we are looking for is smaller than or greater than 100?

○ greater than

○ smaller than

[Submit]

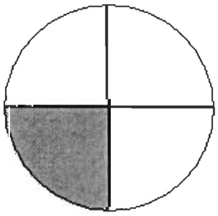
> Remember that we aren't looking for 25% of 100. Instead, 100 is 25% of the number we are looking for.
>
> If 25% of a number is 100, then 100% is greater than 100. Choose "greater than" and click Submit.



Imagine you want to buy a pizza, and you need to find out how much it costs. However, all you know is that 25% of the pizza costs one dollar (that is, 100 cents). What percent would the whole pizza be?

[Submit] [ ]

> The whole pizza would be 100%.
>
> Type in 100.



Now imagine that you asked to cut the pizza into 4 equal parts. What percent would one piece be? [ ]

[Submit]

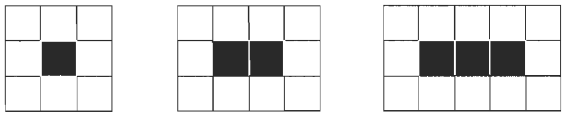
> One whole pizza is equal to 100%. Divide 100% by 4 to find what percent would be equal to one quater of pizza.
>
> 100/4 = 25. Type in 25.

Now let's go back to the original question. If 25% of a number is 100, then what is the number we are looking for?

[Submit] [ ]

> You already know that 25% of the pizza costs 100 cents. So in order to find the total cost, you need to multiply that number by 4.
>
> What's 100*4?
>
> 100*4 = 400. Type in 400.

Year 2002, item 9 (morph)



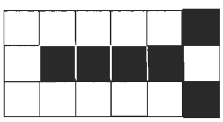
A worker placed white tiles around black tiles in the pattern shown in the three figures above.
Based on this pattern, how many white tiles would be needed for 10 black tiles?

Let me break this down for you.

First, let's try this for 4 tiles. How many white tiles would be needed for 4 black tiles? (Hint: try sketching it)

Submit

Look at the picture below. (The 2 white tiles that had to be added to complete the pattern are highlighted in red)
How many white tiles are needed for 4 black tiles?



Type in 14.

Look at the image above. First, you have a pattern with 3 black tiles. Then you add another black tile to the pattern, which means that you have to add some more white tiles. How many white tiles do you need to add in order to complete the pattern?

Submit

New tiles are highlighted with red.

You need 2 more white tiles. Type in 2.

No. of black tiles	No. of white tiles
1	8
2	8 + 2 = 10
3	10 + 2 = 12
4	12 + 2 = 14

Now look at the table above and try to figure out how many white tiles would be needed for 5 black tiles.

Submit

As you can see from the table, each time you add another black tile, you need 2 more white tiles. If you had a pattern which was made up of 1 black tile and 8 white tiles, and you decided to add another black tile, you would need a total of 10 white tiles in order to complete the pattern.

You need 14 white tiles for 4 black tiles. How many white tiles would you need for 5 black tiles?
Add 2 to 14.
What's 14 + 2?
14 + 2 = 16. Type in 16.

One of the ways you could compute the number of white tiles for 5 black tiles is by using this logic: one needs 8 white tiles for 1 black tile, and each time you add another black tile you need to also add 2 more white tiles. Let's say you have **x** black tiles. You could start with 1 black tile and start adding more black tiles to the pattern one by one. How many black tiles would you have to add to that first tile in order to get **x** black tiles?

- ○ x
- ○ x + 2
- ○ x - 1

Submit

You have one tile and you want to have x tiles. How many more tiles do you need?

(x - 1) + 1 = x. The answer is x - 1.

No. of black tiles	No. of white tiles
1	8
2	8 + (2 – 1) * 2 = 10
3	8 + (3 – 1) * 2 = 12
4	8 + (4 – 1) * 2 = 14
…	…
x	8 + (x – 1) * 2 = ?

Good job. Now look at the table below and try to answer the original question: how many white tiles would be needed for 10 black tiles?

Submit

Substitute 10 for x in the following expression: **8 + (x - 1) * 2**
Type in 26.

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