

**Report Submitted to:**

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# **Analysis of Eight Grade MCAS ITS: The Assistments Project**

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**This project is submitted in partial fulfillment of degree requirements of Worcester Polytechnic Institute**

**This report is part of an educational program, and is to be viewed as partial documentation for the evaluation of academic achievement.**

## **Abstract**

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Intelligent Tutoring Systems have become a focal part of research in the education and computer science fields. Currently there is a 200:1 ratio of creation of an ITS to learning time obtained from the ITS [Anderson and Murry]. A new project known as the Assistments project intends to drastically decrease this ratio to approximately 10:1, by creating a system that is easy to use and deploy to teachers and students.

This paper intends to give the reader the background and future direction of the Assistments project as well as provide recommendations for the Assistments project.

## Executive Summary

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Currently Intelligent Tutoring Systems take too much time to build for the amount of teaching that they provide for students. There is a new project, called the Assistments project that intends to drastically decrease the development time required for and Intelligent Tutor such that use in the classroom is possible.

This paper details the Assistments project starting with a brief history and background knowledge required. This background knowledge includes Intelligent Computer-Assisted Instruction, which is an early form of and ITS, however never was able to mature enough to make it past the academic world. The background knowledge then goes into ITSs as the basis for the Assistments project. Finally the background knowledge is concluded with information about the actual Assistments project.

The remainder of the paper deals with the methodology used to create and assistments, including the interview with the domain expert, scaffolding creation, quality assurance checks and the actual building of the assistment using authoring tools. The paper then goes into the analysis of the data collected during the methodology and conclusions drawn upon that data. This data includes the time required from start to finish of an assistments and an example of an assistment item during the creation process. Finally, some recommendations are made for future development of the Assistments project including documentation and ways in which the creation process could be improved. Some improvements consisted of a better building tool that did not require as much programming knowledge as the current authoring tools.

All items that were collected, notes taken and items created are contained in the appendices under the appropriate titles. This includes the scaffolding template worksheet, original MCAS items and the interview video.

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## **Authorship**

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This document was authored solely by Charles Haines.

## **Acknowledgments**

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I would like to give a special thanks to Professor Hefferenan for being a mentor and a teacher during this entire project. I would also like to thank the entire Assistment team, including the Assistment creators and programmers. Also, I would like to thank the teachers at the schools where the Assistments are being tested.

# Analysis of Eight Grade MCAS ITS: The Assistments Project

## 1.0 Introduction

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In the past education was a luxury that was only affordable for the rich. Only in recent times has the notion of public schooling become common practice for all. The current state of the public education system consisting of large classrooms of 30 or more students is a common place, taught by only a single teacher. In the current state of education, students are not being taught in the best possible method because of sheer numbers of students, lack of teachers and budgets. This is a shame because it has been proven that the the best documented method of instruction is one-on-one tutoring, which allows for the most learning. Bloom states in his book that “it was typically found that the average student under tutoring was about two standard deviations above the control class” [Bloom, 1984]. With the current surge in large classrooms and group based teaching, one-on-one tutoring has now become a luxury for those who can afford it. Currently there exists a plethora of research on how to bring back the personal one-on-one teaching methods that have proven so effective. One possibility to take replace the tutors with computers that can behave exactly as the tutors would behave for a much reduced cost.

The impact of computers in education is only recently being felt on a large scale due to the widespread availability of computers. The promises of multimedia simulation, computer-mediated communication and communities, and Internet-based support for individual and distance learning all have the potential for revolutionary improvements in learning [Forbus & Feltovich, 2001]. With the advent of modern computing power and artificial intelligence, personal tutoring has now become a very viable possibility utilizing “smart” computers. Tutoring would no longer be a luxury and anyone with access to a computer would have a personal tutor at little or no cost. By supplementing large classroom teaching with personal teaching on the computers, each student will receive the personal attention they need at

a much lower cost while still giving the student personalized and individual responses based on the students unique learning abilities [Taylor, 1980].

This project deals with a certain type of computer based instruction know as Intelligent Tutoring Systems. More specifically this project deals with the Assistment project, a four year Department of Education funded project. The Assistment project is being developed collaboratively between Worcester Polytechnic Institute (WPI) and Carnegie Mellon University (CMU). The Assistments project consists of components called “assistments” which are tutoring items based on the Massachusetts Comprehensive Assessment System (MCAS) test. The origin of the word assistment comes from a word play on assessment and assist, as an assistment is designed to assess and assist students performance on the MCAS exams.

The purpose of this paper is to document the creation of assistments and to suggest improvements to help propel the assistments from academic research into the classroom. By the end of this paper, the reader should have gained insight into the Assistment project and understand the rational behind assistments. This paper intends to help take the creation of assistments beyond the current required programming knowledge and into the classroom, where teachers can begin to create assistments themselves. It is with this extension into the classroom where assistments will truly become a feasible solution for providing personal tutoring to students.

## **2.0 Background Knowledge**

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This section intends to give enough background knowledge to the reader so that a better understanding of the concepts related to this project is gained. After reading this background section a reader will become more verse in the terminology and elements of this project and will be able to understand the stance and findings of this project.

### ***2.1 Intelligent Computer-Assisted Instruction (ICAI)***

ICAI systems are used to allow both the student and instruction system a flexibility in the learning environment that closely resembles what actually occurs when a student and a teacher sit down one-on-one and attempt to teach and learn together [Park, Pereze & Seidel 1987]. The ICAI system is designed such that there is tremendous potential in the AI of ICAI. This AI could be very useful in the future to truly model the student-teacher interactions with the student and an intelligent computer. ICAI is currently limited to laboratory studies, however and therefore is not usable in the current education system.

There are many shortcomings of ICAI, which make it unusable for current eduction, however many of the smaller pieces of ICAI are very useful and have lead to research and development of Intelligent Tutoring Systems, which is discussed in the next section.

### ***2.2 Intelligent Tutoring Systems (ITS)***

Intelligent Tutoring Systems (ITS) are computer-based instruction systems that provide individual tutoring to students in a given problem domain. Each ITS has three components:

- knowledge of the domain
- knowledge of the learner
- knowledge of the teacher strategies

The domain refers to the topic or curriculum being taught. The learner refers to the student or user of the ITS. The teacher strategies refer to the methods of teaching and how the material should be presented [Thomas]. These models allow for dynamically generated content to be displayed based on the students progress inside the ITS. For example, certain hints or help may occur if a student gives an expected wrong answer to a question or problem. ITS allow the students to “be involved, active and challenged to reason about the material being presented” [Woolf 2001], which has been proven to be much more effective at teaching than passive methods.

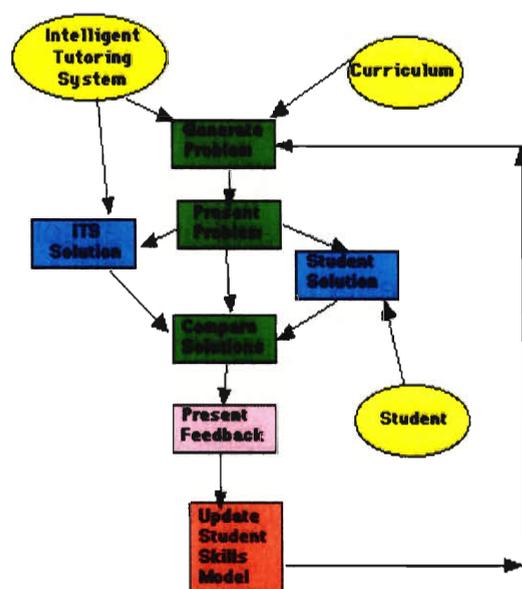
Each ITS must “behave intelligently, not actually be intelligent” [Thomas]. There are a number of things that ITS must be able to do in order to be effective in tutoring and reporting on the progress of students. ITS must be able to:

- accurately diagnose students' knowledge of structures, skills and styles
- diagnose using principles, rather than preprogrammed responses
- decide what to do next
- adapt instruction accordingly
- provide feedback

Drawing 1 shows the basic flow of an ITS.

In the case of ITS, the Artificial Intelligence (AI) is taken from computer science and applied to the specific domain that is being tutored. This allows the computer to analyze the students responses and learning pattern and display dynamic responses as opposed to the previous static content.

“Students do not learn by pressing buttons and flipping pages, even if the page contains images, sound or video.” Since ITS and AI require the



Drawing 1: ITS Flow

Source: SDSU Dept of Educational Tech

<http://coe.sdsu.edu/eet/Articles/tutoringssystem/>

interaction of the student, the student is much more likely to get the true learning experience that comes from having a personal tutor. It is this personal one-on-one teaching that cannot be accomplished in today's schools that the ITSs are looking to put back.

### **2.3 The Assistments Project**

The Assistments project is a four year project, starting in 2003, funded by the U.S. Department of Education's Institute of Education Sciences under the *Effective Mathematics Education Research Grants*. The project intends to provide a web based system which will allow teachers to quickly predict a student's score on a standardized test, provide feedback to teachers to adapt their teaching for their student's needs and provides personal tutoring to the students which may not be available from the teacher because of time, classroom size and budget constraints [Assistments Grant, 2004]. The Assistments project that is currently being developed is being geared towards the Massachusetts Comprehensive Assessment System (MCAS) exam.

The MCAS exam is designed to “measure performance based on the Massachusetts Curriculum Framework,” [MCAS Website, 2004] which consists of English Language Arts, Mathematics, History and Social Science and Science and Technology / Engineering. The current Assistments project only focuses on the Mathematics portions of the MCAS exams at the 8<sup>th</sup> grade school level.

The Java programming language, created by Sun Microsystems is the current platform on which the Assistments are being created. Currently, the assistments project uses Java WebStart to deploy the Assistments for use in the classrooms. Java tomcat and Java servlets are also being used to deploy the assistments to the students in the test classrooms.

## 3.0 Methodology

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This section describes the process that was followed to complete the design and creation of an Assistment. This process is followed in chronological order, however steps of the process may overlap, and the process may repeat all or a portion of itself during the creation of an assistment. This project followed 5 basic steps during the design and creation of a single Assistment. The first step in the process was to interview a domain expert such as a teacher. The interview was video taped so that after the interview was complete the scaffolding worksheet (**See Appendix A**) could be filled out by reviewing the video tape. Once the scaffolding worksheet was filled out, the first quality assurance test was performed on the filled out scaffolding worksheet. Once the first quality assurance test was complete, the designer could then begin creating the actual Assistment using the creation tools. Finally, when the Assistment was finished, the final quality assurance check is performed, and if passed, the Assistment is including in the deployed Assistments.

### ***3.1 Domain Expert Interview***

In order to fully understand the pedagogy of each MCAS item, a domain expert was interviewed so that the designer could create scaffolding that closely resembles the individual teaching of the student. The domain experts were chosen based on their extensive experience in the education field, or their intimate relationship with the Assistments project. By interviewing the teacher, an understanding of how the teacher would “teach” the particular MCAS problem is gained and therefore the most effective scaffolding for the problem can be created. It is through these interviews that the Assistment designer can create scaffolding which will help tutor the student in the same manner in which a teacher would teach the problem therefore fulfilling the purpose of an ITS.

### **3.2 Scaffolding Creation**

After the interview with the domain expert has been completed and video taped, the scaffolding for the MCAS problem is created. This is accomplished by reviewing the video of the interview and filling out the scaffolding worksheet found in Appendix A. The creation of the scaffolding is integral to the design of the Assistment, because it allows the designer to map out the entire Assistment before taking the time to create the actual Assistment. By filling out the scaffolding worksheet instead of creating the Assistment with the authoring tools, the designer can make changes and map out their ideas much quicker and easier. The scaffolding worksheet also allowed for the initial quality assurance testing to be completed much quicker and the results much easier to communicate.

The scaffolding worksheet consisted on many sections, each of which was to be filled out by the designer from the interview video that was collected. The first part of the template provided the information such as the teacher, MCAS item, learning strand and any comments that might be needed for the item. After this section, a picture of the original MCAS question was placed for comparison if the interface and / or question needed to be changed. The next section consisted on the actually scaffolding for the problem and was repeated for as many scaffolding sections as was required. The scaffolding section consisted of the actual scaffolding question, the answer to the question, any hint messages that should be given to the student, the skill from the MCAS framework strand, the particular learning standard within the strand and finally any expected wrong answers. The wrong answers and their related messages were the most important as this helped to further the tutoring process for the students.

To gather a better understanding of the scaffolding worksheet and how it would be completed for a typical MCAS item, **Illustration 1** shows the first page of a completed scaffolding worksheet. Each section is labeled with a

number and the sections are described in more detail below.

1	Teacher or Designer:	
	Date Collected:	
2	MCAS Year:	MCAS Item:
	<u>Learning Standard for Original Item:</u>	
3	<u>Question:</u>	
	<u>Screen Shot or Draw Picture:</u>	
	<u>Plan to Change the Interface:</u>	
4	<u>Scaffolding Question 1:</u>	
	Answer:	
	<u>How Do Students Answer the Question?</u> <u>If multiple choice, list choices. If text input list expected input if appropriate.</u>	
	Hint:	
5	Hint:	
	Hint:	
	Hint:	
6	Skill from MCAS Framework Strand:	
	Particular Learning Standard with that Strand:	
7	Expected Error:	
	Response:	
	Expected Error:	
	Response:	
	Expected Error:	
	Response:	
	Expected Error:	
	Response:	

*Illustration 1: Scaffolding Sections*

Section 1 contains the information about the domain expert interview. It contains the name of the teacher that was interviewed along with the date of the interview.

Section 2 contains the information about the particular MCAS item

including the year of the MCAS and the exact number of the MCAS item. This section also include the original learning strand of the MCAS item from the 39 learning strands development by the Assisments project team.

Section 3 contains the actual MCAS item. The question section is the actual question from the MCAS test and the screen shot is a shot of the MCAS item taken straight from the MCAS PDF downloaded from the MCAS website. Finally, for some MCAS items, the question had to be modified to fit in the Assisments authoring tools.

Sections 4, 5, 6 and 7 are the scaffolding sections. There could be as man of these scaffolding sections as was needed to complete all the scaffolding. Section 4 contains the scaffolding question along with the answer. This section also contains how the student would answers the question; for example if it was multiple choice, this sections would contain the choices.

Section 5 contained the hint messages that the students could view as they were answering the scaffolding question. These hints were designed to help aid them in coming up with the answer to the scaffolding.

Sections 6 contains the MCAS skill strand and the particular learning standard within that strand. Since scaffolding could have different learning strategies than the original question, this was needed to help understand how to proceed with helping the student.

Section 7 contained and expected wrong answers the student might give while attempting to answer the scaffolding. These expected wrong answers allowed the computer to react and teach the student based on common mistakes that students make.

### ***3.3 First Quality Assurance Test***

Since each Assisment would be used by real students to aid in their learning, quality assurance was taken very seriously to ensure that no Assisment would not perform it's primary purpose. Once the scaffolding

worksheet was filled out, the first of two quality assurance tests was performed on the filled out worksheet. The quality assurance expert reviewed the worksheet to ensure that that scaffolding was correct both grammatically and pedagogically. Once the worksheet passed this testing, which could take multiple checks and revisions by the QA expert and the designer, the design could move on to the actual creation of the Assistment using the authoring tools.

### ***3.4 Assistment Creation Using Authoring Tools***

Assistments are created using authoring tools that were written as a Java Bean imported into the Netbeans Integrated Development Environment (IDE). The Java Bean was created as a collaborative effort between Worcester Polytechnic Institute (WPI) and Carnegie Mellon University (CMU). Netbeans is an open sourced development environment that was developed by Sun Microsystems and is freely available from <http://www.netbeans.org>. There was an initial learning curve for creating Assistments, however once the process was learned, it was very simple. The process of creating Assistments consisted of dragging and dropping components, called DorminWidgets, onto the Assistments canvas and then adding the appropriate text to these widgets. DorminWidgets consisted of components such as text boxes, combo boxes and check boxes. The process consisted of creating the user interface to the Assistment that the student would use. Once the user interface was created, the designer created the actual behavior of the Assistment. Exact instructions on how to build an Assistment can be found on the Assistment website, <http://www.assistment.com>.

### ***3.5 Second Quality Assurance Test***

Once the designer created the user interface and the behavior for the Assistment, the final quality assurance test was performed. The final QA test consisted of taking the completed Assistment back to the original domain

expert and having them scrupulously look over the entire thing. If the domain expert concluded that the Assistment was useful for the tutoring of students, it was finalized and added to the Assistment repository so that it could be included in future curriculum to be given to the students. If the domain expert concluded that the Assistments was not satisfactory, the designer would change the Assistment according to their suggestions and then have it reviewed again. This process continued until the domain expert concluded the Assistment was satisfactory and could then be finalized and added to the Assistment repository.

## 4.0 Data Analysis

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The purpose of this section is to describe the data collection and analysis portion of the Assistment creation. Metrics were gathered for each individual Assistment as it was created, which allowed for analysis continually during the course of the entire project. Each metric that was gathered allow for the prediction of time for the next Assistment to be much more accurate and well as laying a foundation for each Assistment following it to be created.

### 4.1 Design Process

The design process for Assistment building can be broken down into four distinct categories, of which some categories were visited more than once during the design phase. The design process always started with an interview of a domain expert and always was finished with a final quality assurance test. Once the design process was completed, the Assistment was deployed and used in the classrooms.

One goal of this project was to time the design process for creating Assistments and to be able to cite places where improvements could be made in order to speed up the creation process for programmers and non-programmers. This is accomplished by breaking down the project into sections and then timing each section. As one becomes more verse in the Assistment creation process, the time for each section as well as the total time should decrease. The sections listed in the table below were evaluated for this project.

<b><i>Assistment Design and Creation Process</i></b>	
Domain Knowledge Gathering	This section consisted of deciding which MCAS items to create as well as interviewing the domain expert to gather the scaffolding for each item

<b><i>Assistment Design and Creation Process</i></b>	
Scaffolding Creation	This section consisted of reviewing the interview video tape and filling out the scaffolding worksheet located in Appendix A
Quality Assurance	<p>This section consisted of the two quality assurance test checks that were performed, sometimes multiple times, over the course of the Assistment creation. Specifically, the two quality assurance tests that were performed were:</p> <ul style="list-style-type: none"> <li>● On the scaffolding worksheet filled out from the interview video</li> <li>● By a domain expert on the completed Assistment</li> </ul>
Assistment Creation	This section involves using the authoring tools to create the actual Assistment

These four categories will be evaluated in section 4.4 for all the Assistments created in this project and conclusions will be drawn based on these times.

## ***4.2 Interviews***

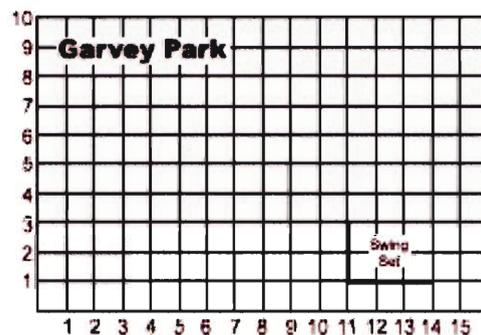
Most of the domain gathering knowledge consisted of interviewing a domain expert and video recording the interview (**See Appendix D**). Each interview was done in Worcester, Massachusetts with a cooperating teacher with 7 years experience teaching middle school mathematics. The interviews lasted a little more than an hour and once completed, enabled the completion of scaffolding worksheets for 6 MCAS items (**See Appendix B for completed scaffolding worksheets**), some of which could be broken into multiple Assistments.

## ***4.3 Assistment Creation***

Assistments were created using WYSIWYG (What You See Is What You Get) authoring tools. The authoring tools ran in the NetBeans IDE. The main Authoring tools windowed is shown in Illustration 2 after starting a new assistment.

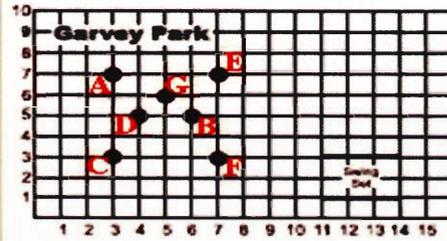


is put onto the assistment. The original question can be asked in the form of a text box answer, multiple choice, drop down box or check boxes. The original MCAS item for this example is shown in Illustration 4. Once the original question is put on the assistment, it is time to create the scaffolding. This is done by dragging the appropriate domain widget onto the assistment, until all scaffolding has been completed. Illustration 5 shows the building of scaffolding for an assistment. Once the scaffolding has been created, the assistment must be told how to behave based on the student's interactions with the system. This is done using another portion of the authoring tools. To map the interaction of the students with the programs responses a brd (behavior recording diagram) was created using the tool show in Illustration 6. The brd creator resembled a tree like structure which allowed the developer to map the flow of the program and to map expected answers and inputs from the student to the computers response. Once this brd file was completed the assistment was ready to be tested and deployed. Illustration 7 shows a completed brd file and it's tree mapping in the brd creator tool.

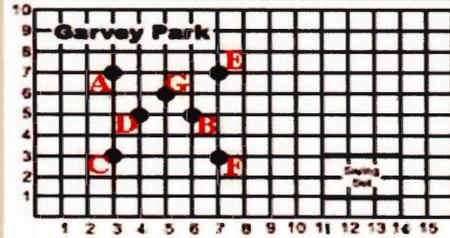


25. The swing set in Garvey Park is going to be moved from the place shown on the map to a new location. One corner of the set will be at (3,7) and another corner will be at (6,5). Write the coordinates of the points where the other two corners will be.

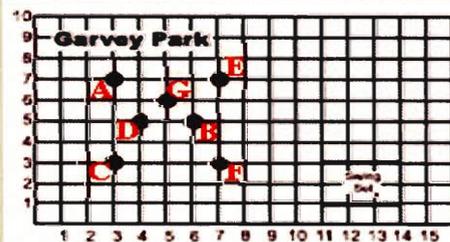
*Illustration 4: Original MCAS Item*



Let's break the problem down some. What is the letter of the point with the coordinate (3,7) on the above graph? Smudge image S



Good, what is the letter of the point with the coordinate (6,5) on the above graph?



Correct, if the swing set has its corners on A and B, what other two letters would be the other two corners of the swing set?

- A
- B
- C
- D
- E
- F
- G
- H

Finally, what are the coordinates of the other two corners of the swing set?

- (3 5)
- (5 3)
- (6 7)
- (7 5)
- (3 7)
- (6 5)



Illustration 5: Scaffolding Creation

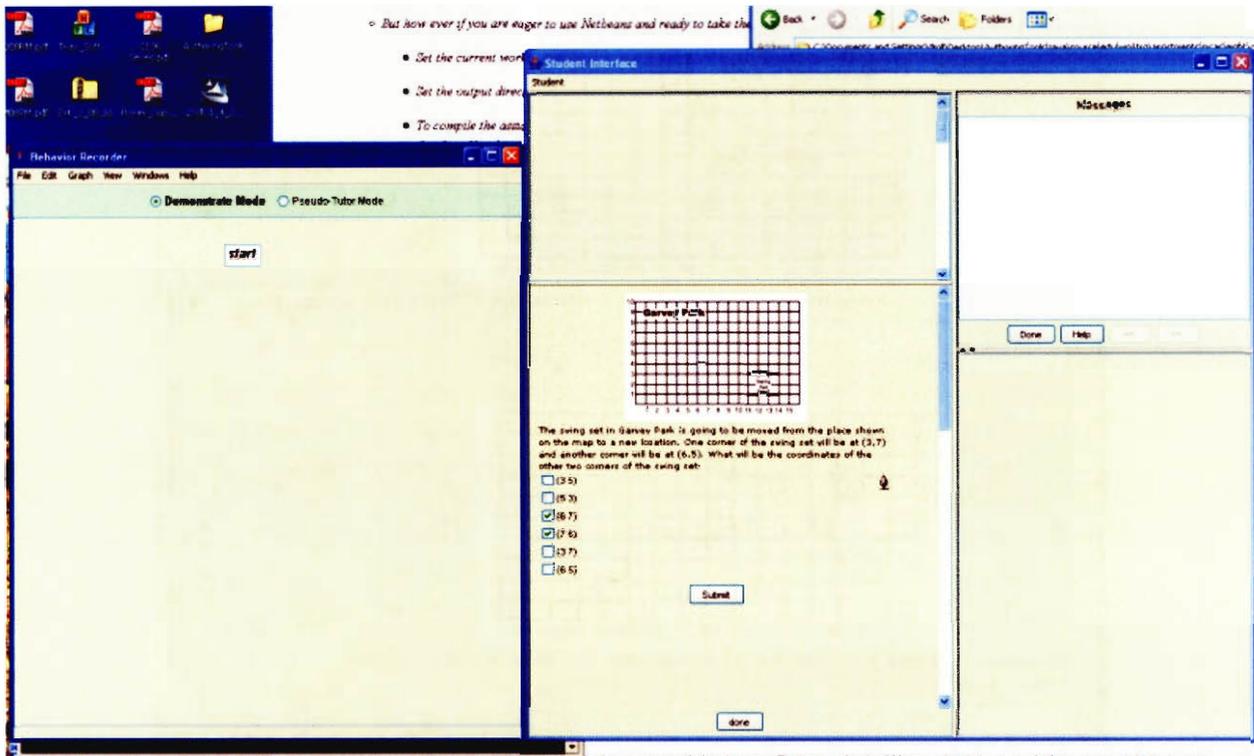


Illustration 6: BRD Creation Tool

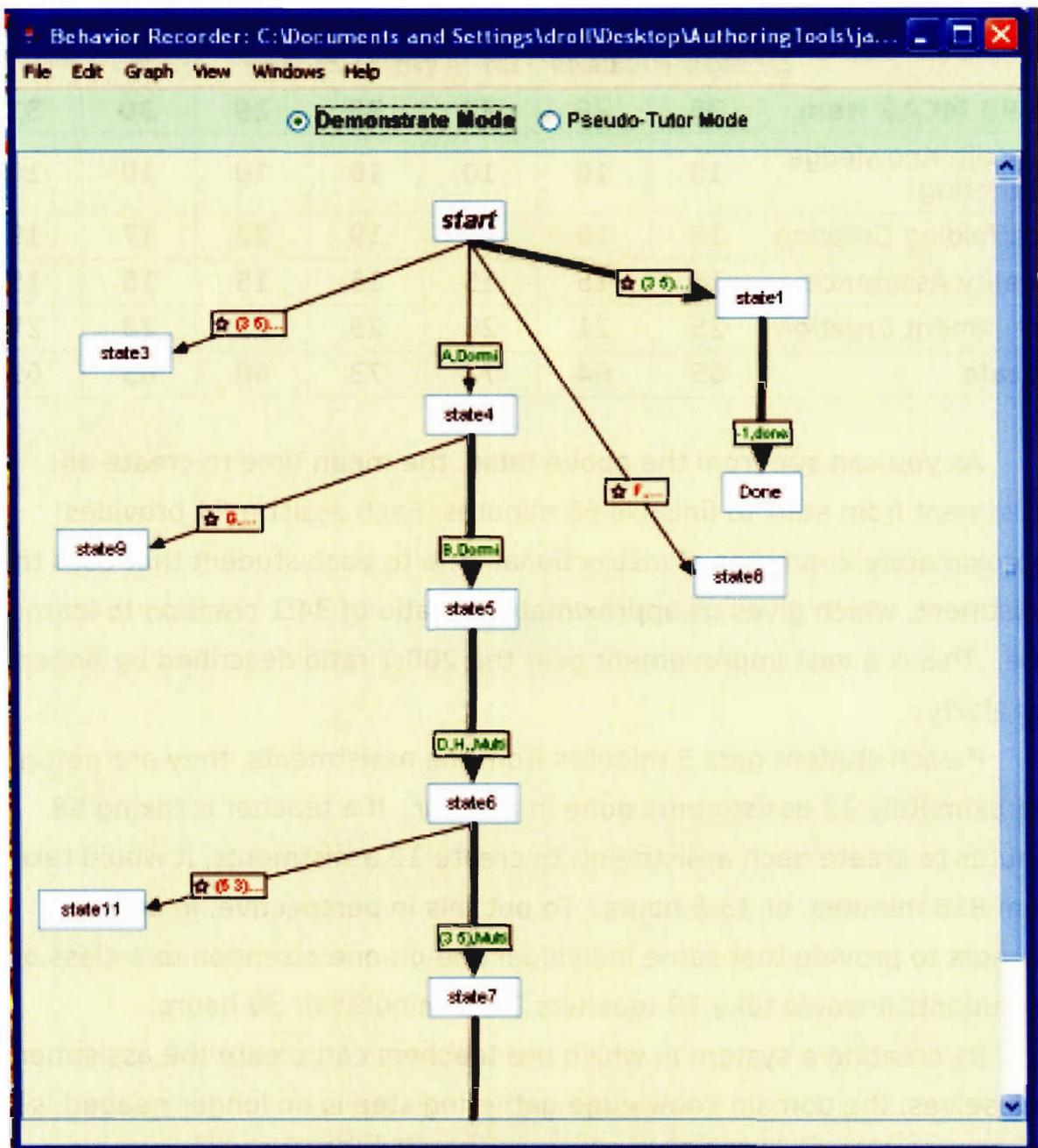


Illustration 7: Completed BRD File

## 4.4 Comparisons

The table below summarizes the times for the entire design and creation of an assistment from an MCAS item.

<b><i>Design Process Times (in minutes)</i></b>							
<b>1998 MCAS Item</b>	<b>25</b>	<b>26</b>	<b>27</b>	<b>28</b>	<b>29</b>	<b>30</b>	<b>31</b>
Domain Knowledge Gathering	10	10	10	10	10	10	10
Scaffolding Creation	15	18	21	19	22	17	19
Quality Assurance	15	15	15	15	15	15	15
Assistment Creation	25	21	26	29	21	23	25
<b>Totals</b>	<b>65</b>	<b>64</b>	<b>72</b>	<b>73</b>	<b>68</b>	<b>65</b>	<b>69</b>

As you can see from the above table, the mean time to create an assistment from start to finish is 68 minutes. Each assistment provides approximately 2 minutes of instructional time to each student that uses the assistment, which gives us approximately a ratio of 34:1 creation to learning time. This is a vast improvement over the 200:1 ratio described by Anderson and Murry.

If each student gets 5 minutes from the assistments, they are getting approximately 12 assistments done in an hour. If a teacher is taking 68 minutes to create each assistment, to create 12 assistments, it would take them 816 minutes, or 13.6 hours. To put this in perspective, in order for teachers to provide that same individual one-on-one attention to a class of 30 students it would take 30 teachers 1600 minutes or 30 hours.

By creating a system in which the teachers can create the assistments themselves, the domain knowledge gathering step is no longer needed, since the domain expert will be the person creating the assistment. Also, often times the interview video needed to be reviewed multiple times to get the correct scaffolding. Since the domain expert would be doing the scaffolding

template themselves, the scaffolding creation would take approximately half as long.

#### **4.5 Summary**

As can be seen from the information above, ITS can drastically increase the number of students that can receive one-on-one tutoring utilizing only a single teacher. This one-on-one tutoring is integral to the teaching of students and by using ITS, this one-on-one tutoring that has now become a luxury can once again be afforded to each and every student. Obviously the ITS cannot completely replace a teacher, however it can provide much assistance to both the students and the teachers.

## **5.0 Conclusions and Recommendations**

The Assistment project helps a tremendous amount in the goal of intelligent tutoring systems. The assistments are fairly easy to build and are getting easier with each iteration of the project. Currently assistments take around an hour for a non-domain expert who has experience with the system to build and approximately 45 minutes for a domain expert. The amount of learning time that comes from these assistments is a great help in giving students the one-on-one attention that each student needs to learn successfully.

There are however many improvements that could be incorporated into the assistments in order to further their goals of tutoring students. There are two distinct categories of improvements that could occur to help further the assistments project and help to make them a truly viable solution for one-on-one tutoring for students. The two main categories are ease of use and accessibility. Ease of use consists of elements such as the actual creation of the assistment and the documentation that exists on the building of assistments. Accessibility consists of elements that allow for students with disabilities to use assistments with the same success rate as those students without disabilities. It also incorporates translation of the assistments into other languages so that assistments can reach those non English speaking countries and students.

### **5.1 Assistment Creation**

Currently the assistment creation process requires a good bit of computer science knowledge. In order to create and assistment one must install NetBeans and the authoring tools, which can be rather difficult at the present time. If the assistment building process were designed such that a user did not require the installation of a program and then the authoring tools, the creation process would be much easier and would not require an extensive knowledge of computer science. This is currently being

implemented in the “next generation” of assistments as it is completely web based. The authoring system should not require the builder to have to build the interface for the assistment, rather the builder should concentrate on simply inputting the scaffolding into the system. The actual creation of the user interface should be done by the underlying Assistment creator. If the Assistment creator can be made so that the builder only has to worry about scaffolding and making the system seem “intelligent” and not worry about user interface issues, the system will much more usable by domain experts. If the system is more usable by domain experts, the assistments get created much quicker and the usability of assistments tremendously increases.

## **5.2 Documentation**

Documentation of the assistment project currently lacks. In order for the assistments to be used in classrooms and designed by teachers, there must exist documentation that explains the creation of assistments. This documentation should exist in two forms, in the assistment creator and on-line. If there were tutorials that showed a creator the whole process of creating an assistment, it would be much easier for a person who has never created any assistments to pick the creation process up with a very shallow learning curve. Since very little documentation or tutorials currently exist, the learning curve for creating an assistment can be fairly high depending on the creator's competence in computer science. It would also be very useful if the assistment creator had a built-in help section that also included a search tool. This would be much like the documentation and search functions that come with popular programs like Microsoft Word. This will enable a creator to answer problems and questions that might arise very quickly. If these few documentation issues were fixed, the initial creation of assistments would have much shallower learning curve and would enable speed improvements even in experienced assistment builders.

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## **Appendix A – Scaffolding Worksheet Template**

The form on the following pages was filled out from the video taped sessions with the domain experts. Only one scaffolding section is shown, however there could be as many scaffolding sections as was needed.

Teacher or Designer: \_\_\_\_\_

Date Collected: \_\_\_\_\_

MCAS Year: \_\_\_\_\_ MCAS Item: \_\_\_\_\_

Learning Standard for Original Item:

Question:

Screen Shot or Draw Picture:

Plan to Change the Interface: \_\_\_\_\_

Scaffolding Question 1:

Answer: \_\_\_\_\_

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint:

Hint:

Hint:

Skill from MCAS Framework Strand: \_\_\_\_\_

Particular Learning Standard with that Strand: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

## **Appendix B – Completed Scaffolding Worksheets**

The following pages contain the completed scaffolding worksheets for MCAS items 25-31 of the 1998 MCAS. The words marked in blue are typed from the video taped domain expert interview.

Teacher or Designer: CH

Date Collected: April 18, 2004

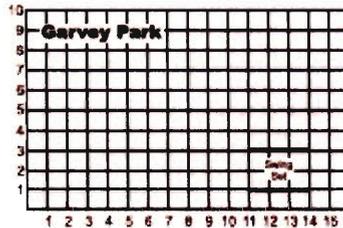
MCAS Year: 1998 MCAS Item: Item 25

Learning Standard for Original Item:  
Geometry

Question:

The swing set in Garvey Park is going to be moved from the place shown on the map to a new location. One corner of the set will be at (3,7) and another corner will be at (6,5). What will be the coordinates of the other two corners?

Screen Shot or Draw Picture:



25. The swing set in Garvey Park is going to be moved from the place shown on the map to a new location. One corner of the set will be at (3,7) and another corner will be at (6,5). Write the coordinates of the points where the other two corners will be.

Plan to Change the Interface: No

Scaffolding Question 1:

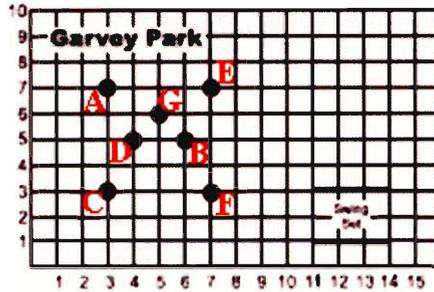
What is the name of the point with coordinates (3,7) on this graph?

Answer: A

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

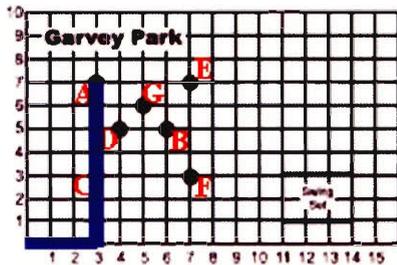
Students will have the following picture to choose from a set of points.



Hint: The first value in the coordinate pair tells you the x-value which is along the horizontal axis. The second value in the coordinate pair tells you the y-value which is along the vertical axis.

Hint: The coordinate (3,7) tells you to go over 3 and then up 7 on the graph.

Hint:



Skill from MCAS Framework Strand: Geometry

Particular Learning Standard with that Strand:

G.6.8-understanding-plane-transformations

Expected Error: F

Response: The first value in the coordinate pair tells you the x-value which is along the horizontal axis. The second value in the coordinate pair tells you the y-value which is along the vertical axis.

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Scaffolding Question 2:

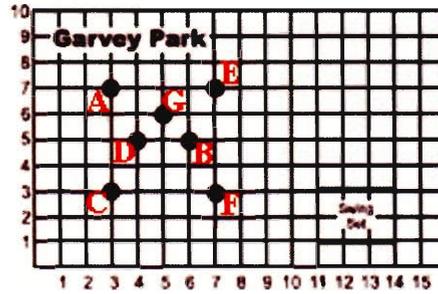
Where is the coordinate (6,5) located on the graph?

Answer: B

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

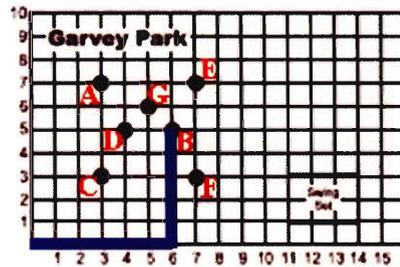
Students will have the following picture to choose from a set of points.



Hint: The first value in the coordinate pair tells you the x-value which is along the horizontal axis. The second value in the coordinate pair tells you the y-value which is along the vertical axis.

Hint: The coordinate (6,5) tells you to go over 6 and then up 5 on the graph.

Hint:



Skill from MCAS Framework Strand: Geometry

Particular Learning Standard with that Strand:

G.6.8-understanding-plane-transformations

Expected Error: G

Response: The first value in the coordinate pair tells you the x-value which is along the horizontal axis. The second value in the coordinate pair tells you the y-value which is along the vertical axis.

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

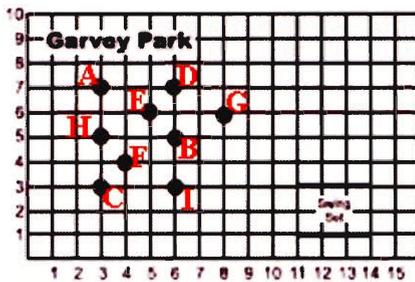
Scaffolding Question 3:

If the swing set has its corners on A and B, what other two letters would be the other two corners of the swing set?

Answer: D and H

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.  
Students are given the following graph with the following points and must choose the correct letters with check boxes.



- Hint: The dimensions on the swing set at the new points should be the same as the dimensions on the old swing set.
- Hint: The old swing set was 3 units wide and 2 units tall.
- Hint: 3 units to the right of A is D, and 2 units down from A is H. Select A and H.

Skill from MCAS Framework Strand: Geometry  
Particular Learning Standard with that Strand: G.6.8-understanding-plane-transformations

- Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Scaffolding Question 4:

Finally, what are the coordinates of the other two corners of the swing set?

Answer: A and C

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

- A. (3,5)
- B. (5,3)
- C. (6,7)
- D. (7,6)
- E. (3,7)
- F. (6,5)

Hint: To determine the coordinates of a point, you put the x-axis coordinate first, then the y-axis coordinate.

Hint:

Hint:

Skill from MCAS Framework Strand: Geometry  
Particular Learning Standard with that Strand: G.6.8-understanding-plane-transformations

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Teacher or Designer: CH

Date Collected: April 18, 2004

MCAS Year: 1998 MCAS Item: Item 26

Learning Standard for Original Item:  
Number Sense

Question:

Roberto bought skates marked \$69.95. The rate of sales tax is 5%. How much will Roberto have to pay to purchase the skates?

Screen Shot or Draw Picture:

26. Roberto bought skates marked \$69.95. The rate of sales tax is 5%. How much will Roberto have to pay to purchase the skates?

Plan to Change the Interface: \_\_\_\_\_

Scaffolding Question 1:

Sales tax is 5%. How much will Roberto pay for sales tax for these skates?

Answer: 3.50

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint: 5% is half of 10%, find 10% of the price of the skates.

Hint: To find 10%, you move the decimal point to the left one place.

Hint: 10% of \$69.95 is \$6.995 which rounds to \$7.00.

Hint: To find 5% take half of 10%, which was \$7.00.

Hint: Half of \$7.00 is \$3.50. Type 3.50

Skill from MCAS Framework Strand: Number Sense

Particular Learning Standard with that Strand: N.12.8-using-appropriate-operations-with-rational-numbers

Expected Error: 3.5

Response: Dollar amounts are expressed with two digits after the decimal. If there is only one digit after the decimal, add another zero to make the correct number of digits after the decimal point.

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Scaffolding Question 2:

How much will Roberto have to pay to purchase the skates?

Answer: \$73.45 or \$73.44, depending on how they rounded.

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint: Add the sales tax onto the original price.

Hint: Add \$69.95 plus \$3.50.

Hint: The change is \$0.95 and \$0.50.  $\$0.90 + \$0.50 = \$1.45$ .

Hint: The dollars are \$69 and \$3.  $\$69 + \$3 = \$72$ .

Hint: Now add up the dollar amount and the change amount.

Hint: The dollar amount is \$72 and the change amount was \$1.45.  $\$72 + \$1.45 = \$73.45$ . Enter 73.45.

Skill from MCAS Framework Strand: Number Sense

Particular Learning Standard with that Strand: N.12.8-using-appropriate-operations-with-rational-numbers

Expected Error: 73.4475  
Response: Dollar amounts are only expressed with two digits after the decimal point. Round the number if it extends more than two decimal places.

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Teacher or Designer: CH

Date Collected: April 21, 2004

MCAS Year: 1998 MCAS Item: Item 27 Part 1

Learning Standard for Original Item:  
Number Sense

Question:

Chris spends \$9 of the \$12 he gets for his birthday. What fraction of his birthday money did he spend? Be sure to reduce your fraction to the lowest terms.

Screen Shot or Draw Picture:

27. Chris spent \$9 of the \$12 he was given for his birthday.

- His brother Luis says that Chris has spent exactly  $\frac{2}{3}$  of the birthday money.
- His sister Jessie says that he has spent exactly 0.75 of the money.
- His other sister Mary says that he has spent exactly 80% of the money.

Chris wonders who is correct.

For each of the three—Luis, Jessie, and Mary—tell whether he or she is correct or incorrect.

Explain your reasoning.

Plan to Change the Interface: Yes

Scaffolding Question 1:

Chris spends \$9 of the \$12 he gets for his birthday. What fraction of his birthday money did he spend? Be sure to reduce your fraction to the lowest terms.

Answer:  $\frac{3}{4}$

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint: The fraction is the part he spent over the total amount he had.

Hint: The part that he spent was 9, the total amount that he had was 12.

Hint: The fraction would be  $\frac{9}{12}$ . Now reduce  $\frac{9}{12}$  to its lowest terms.

Hint: To reduce a fraction to its lowest terms, you find the largest number that both the numerator (number in the top of the fraction) and the denominator (number in the bottom of the fraction) are divisible by.

Hint:  $\frac{9}{12}$  reduced is  $\frac{3}{4}$ .

Skill from MCAS Framework Strand: Number Sense

Particular Learning Standard with that Strand:

N.1.8-understanding-number-representations

Expected Error: 9/12

Response: 9/12 can be reduced to a lower fraction. To reduce a fraction to its lowest form, you find the largest number that both the numerator (number in the top of the fraction) and the denominator (number in the bottom of the fraction) are divisible by.

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Teacher or Designer: CH

Date Collected: April 18, 2004

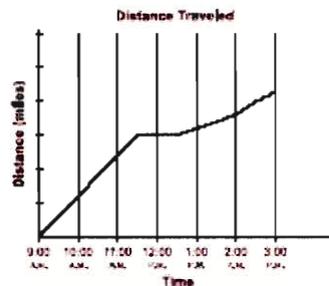
MCAS Year: 1998 MCAS Item: Item 28

Learning Standard for Original Item:  
Data Analysis

Question:

There is no original question, this question is scaffolding only because of the nature of the free response question.

Screen Shot or Draw Picture:

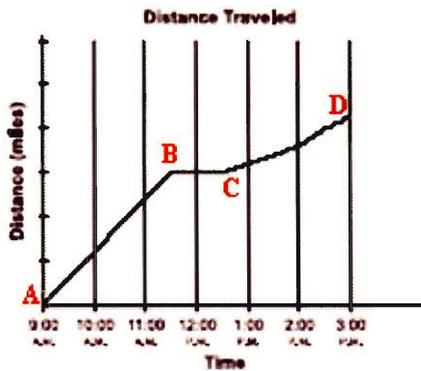


28. The members of the Bike Club rode from the city to their camp. Sean kept track of how far they had traveled throughout the day and made this graph.

Write a brief story about their trip that accounts for all the changes shown in the graph. Include just enough detail about the different speeds and activities to account for the changes. Be sure to identify the time of each event in your story.

Plan to Change the Interface: Yes

Scaffolding Question 1:



Which of the following describes what happened as the Bike Club biked from point A to point B on the above graph?

Answer:  D

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

- A. They rested and did not bike at all.
- B. They changed speeds while they were biking.
- C. Their speed increased as they biked.
- D. They biked at a constant speed.

Hint: The slope of a line tells you what their speed was during the course of the ride.

Hint: The slope of the line from point A to point B is constant.

Hint: If the slope of the line is constant, it tells you they biked at a constant speed.

Skill from MCAS Framework Strand:  P.5.8

Particular Learning Standard with that Strand:

P.5.8-understanding-lineslope-concept

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Scaffolding Question 2:

Which of the following describes what happened as the Bike Club biked from point B to point C on the graph above?

Answer:   A  

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

- A. They rested and did not bike at all.
- B. They change speeds while they were biking.
- C. Their speed increased as their biked.
- D. They biked at a constant speed.

Hint: The slope of a line tells you what their speed was during the course of the ride.

Hint: The slope of the line from point B to point C is zero.

Hint: Since the slope is zero, it means they did not have any speed Therefore, they rested and did not bike at all during this period.

Skill from MCAS Framework Strand:   P.5.8  

Particular Learning Standard with that Strand:

  P.5.8-understanding-lineslope-concept  

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Scaffolding Question 3:

Which of the following describes what happened as the Bike Club biked from point C to point D on the graph above?

Answer:   C  

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

- G. A. They rested and did not bike at all.
- H. B. They change speeds while they were biking.
- I. C. Their speed increased as their biked.
- J. D. They biked at a constant speed.

Hint: The slope of a line tells you what their speed was during the course of the ride.

Hint: The slope of the line from point C to D was continually increasing.

Hint: Since the slope of the line was continually increasing, it means that their speed was increasing as they biked.

Skill from MCAS Framework Strand: P.5.8

Particular Learning Standard with that  
Strand:

P.5.8-understanding-lineslope-  
concept

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Teacher or Designer: CH

Date Collected: April 18, 2004

MCAS Year: 1998 MCAS Item: Item 29 Part A

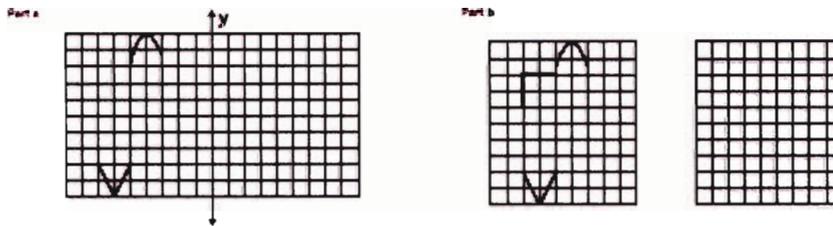
Learning Standard for Original Item:  
Geometry

Question:

The figure shown above is to be reflected over the line  $y$ . Which of the following shows the figure above being reflected over the line  $y$ ?

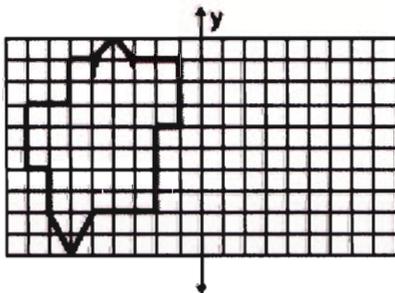
Screen Shot or Draw Picture:

29. a. The figure shown in Part a of your Student Answer Booklet [shown below] is to be reflected over line  $y$ . Draw the reflected figure.
- b. The figure shown in Part b of your Student Answer Booklet [shown below] is to be reduced so that its dimensions are  $\frac{1}{2}$  their original size. On the blank grid [shown below], draw a copy of the figure that is exactly the same shape but has dimensions that are only  $\frac{1}{2}$  of those of the original.



Plan to Change the Interface: Yes

Scaffolding Question 1:

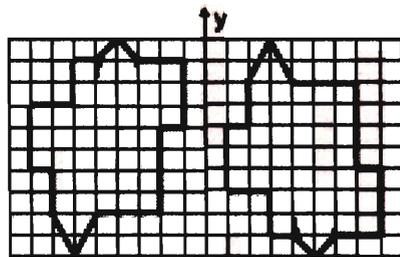


The figure shown above is to be reflected over line  $y$ . Which of the following shows the figure above being reflected over line  $y$ ?

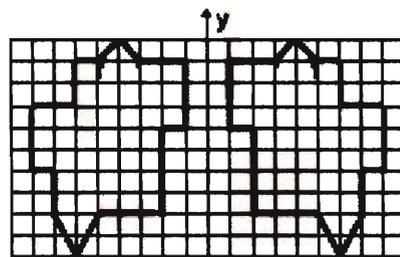
Answer: \_\_\_\_\_

How Do Students Answer the Question?

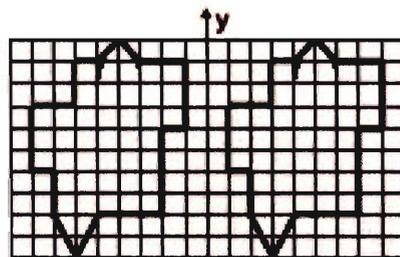
If multiple choice, list choices. If text input list expected input if appropriate.



K. a.



L. b.



M. c.

Hint: The reflection of an image is the mirror image, meaning the reflected image would appear as if you were looking at the original in a mirror.

Hint: Points that are far away from the y-axis in the original image are also far away from the y-axis in the mirror image.

Hint:

Skill from MCAS Framework Strand: \_\_\_\_\_

Particular Learning Standard with that

Strand: \_\_\_\_\_

Expected Error: A

Response: This figure has been rotated and translated.

Expected Error: C

Response: This figure has been translated.

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Teacher or Designer: CH

Date Collected: April 18, 2004

MCAS Year: 1998 MCAS Item: Item 30 Part A

Learning Standard for Original Item:  
Data Analysis

Question:

The table below shows the number of points that Luna scored in his last 10 games of the season. Find the mean number of points scored by Luna.

Screen Shot or Draw Picture:

30. The coach for the All-Star Basketball Game needs to pick one of two players for the team. The table below shows the number of points each of the players scored in his last 10 games.

Name of player	Number of points scored in last ten games
Geltz	18, 32, 28, 18, 14, 28, 10, 16, 36, 20
Luna	22, 17, 23, 8, 24, 24, 22, 20, 18, 22

- Find the mean (average) number of points scored by each player. Show or describe how you found the means.
- Find the median number of points scored by each player. Show or describe how you found the medians.

Plan to Change the Interface: Yes

Scaffolding Question 1:

What is the definition of mean?

Answer: C

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

- N. A. Middle number of a set.
- O. B. Number occurring most often in a set.
- P. C. Average of the numbers in a set.

Hint: The mean is the average of the numbers in a set.

Hint:

Hint:

Skill from MCAS Framework Strand: Data Analysis

Particular Learning Standard with that Strand:

D.3.8-understanding-data-representation-techniques

Expected Error: A

Response: The middle number of a set is the median.

Expected Error: B

Response: The number occurring most often in a set is the mode.

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Scaffolding Question 2:

Correct, now how many games did Luna play?

Answer: 10

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint: Luna played 10 games.

Hint:

Hint:

Skill from MCAS Framework Strand: Data Analysis

Particular Learning Standard with that Strand:

D.3.8-understanding-data-representation-techniques

Expected Error: \_\_\_\_\_

Response: \_\_\_\_\_

Scaffolding Question 3:

What is the total number of points he scored over the 10 games he played?

Answer: 200

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint: Add up all of the points in the table for Luna.  
Hint: Luna scored 200 total points.  
Hint:

Skill from MCAS Framework Strand: Number Sense  
Particular Learning Standard with that Strand: N.8.8-applying-properties-of-operators

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Scaffolding Question 4:  
Finally, what is the mean points scored for Luna?

Answer: 20

How Do Students Answer the Question?  
If multiple choice, list choices. If text input list expected input if appropriate.

Hint: To find the mean, take the total number of points and divide the total by the number of games that were played.  
Hint: He scored 200 points and played 10 games. Take 200 and divide by 10.  
Hint:  $200 / 10 = 20$ . His mean points scored is 20.

Skill from MCAS Framework Strand: Data Analysis  
Particular Learning Standard with that Strand: D.3.8-understanding-data-representation-techniques

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_  
Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

Teacher or Designer: CH

Date Collected: April 18, 2004

MCAS Year: 1998 MCAS Item: Item 31 Part A

Learning Standard for Original Item:  
Measurement

Question:

At the end of every 2nd mile of the Boston Marathon, a typical marathon runner takes about 4 ounces of water. At this rate, about how many ounces of water would an average runner take in an entire 26.2-mile marathon?

Screen Shot or Draw Picture:

31. At the end of every 2nd mile of the Boston Marathon, a typical marathon runner takes about 4 ounces of water. Instead of drinking all the water, the runner sips some of it and then throws the rest on his or her head or body to cool off.
  - a. At this rate, about how many ounces of water would an average runner take in an entire 26.2-mile marathon? Explain how you found your answer.
  - b. At this rate, about how many pints of water would an average runner take in an entire 26.2-mile marathon? Explain how you found your answer.
  - c. Suppose that all the runners in the Boston Marathon behaved like the "typical" marathon runner described above. About how many gallons of water would have been used by the 40,700 runners in the 1996 Boston Marathon? Explain each step you used to find your answer.

Plan to Change the Interface: Yes

Scaffolding Question 1:

At the end of every 2nd mile of the Boston Marathon, a typical marathon runner takes about 4 ounces of water. At this rate, about how many ounces of water would an average runner take in an entire 26.2-mile marathon?

Answer: 52

How Do Students Answer the Question?

If multiple choice, list choices. If text input list expected input if appropriate.

Hint: If a runner takes the water every 2 miles, find out how many times he or she takes the water.

Hint: The runner would take the water 13 times.

Hint:  $13 \times 4 = 52$ . The runner would take 52 oz of water.

Skill from MCAS Framework Strand: \_\_\_\_\_  
Particular Learning Standard with that  
Strand: \_\_\_\_\_

Expected Error: \_\_\_\_\_  
Response: \_\_\_\_\_

## Appendix C – MCAS Items

The following are screen shots of the completed assistments for this project.

The screenshot shows a software window titled "Student Interface" with a "Student" header. The main area contains two math problems. The first problem features a coordinate grid labeled "Garvey Park" with x and y axes from 1 to 15. A swing set is shown at the intersection of x=10 and y=3. The text asks for the coordinates of the other two corners of a square with one corner at (3,7) and another at (6,5). Below the text are five radio button options: (3,5), (5,3), (6,7), (7,6), and (6,5). A "Submit" button is located below the options. The second problem uses the same grid with six points labeled A through F. Point A is at (3,7), B at (4,5), C at (3,3), D at (4,4), E at (6,5), and F at (7,3). The text asks for the letter of the point with the coordinate (3,7). Below the text is an empty text input field and a "done" button. On the right side of the interface is a "Messages" panel with the text: "The first value in the coordinate pair tells you the x-value which is along the horizontal (right-left) axis. The second value in the coordinate pair tells you the y-value which is along the vertical (up-down) axis." Below the message are buttons for "Done", "Help", and navigation arrows.

Illustration 8: Item 25, Year 1998

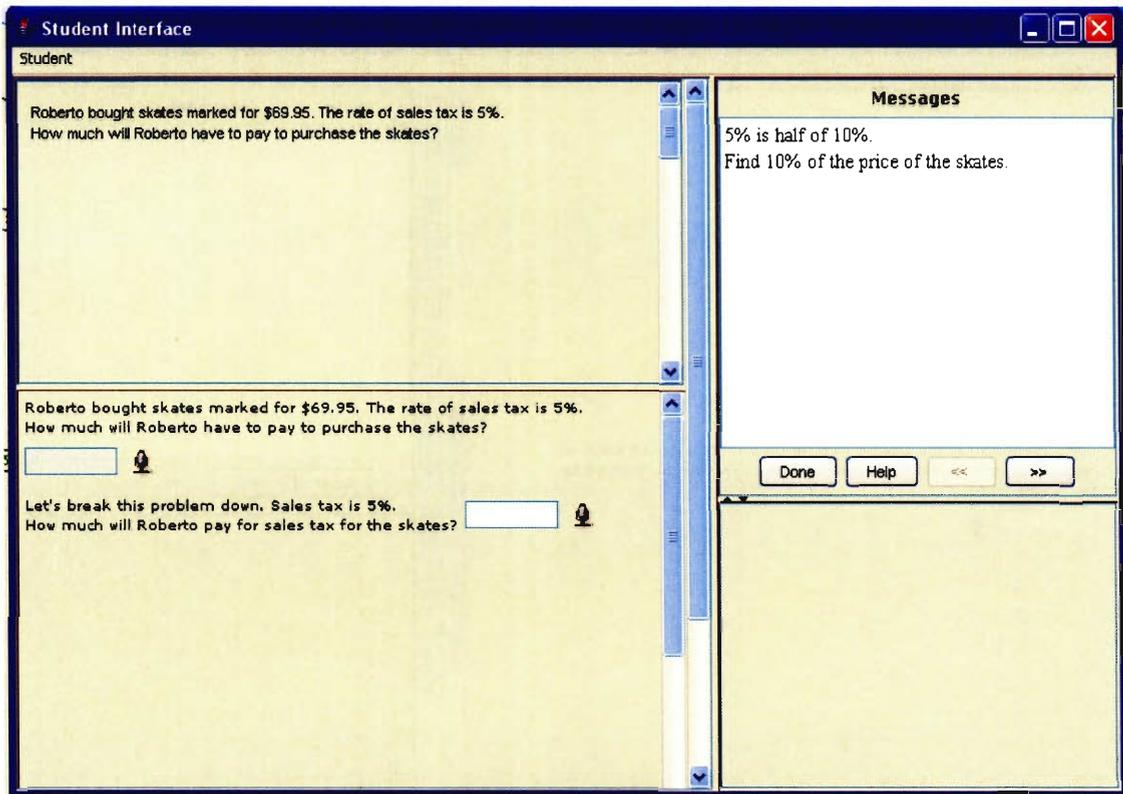


Illustration 9: Item 26, Year 1998

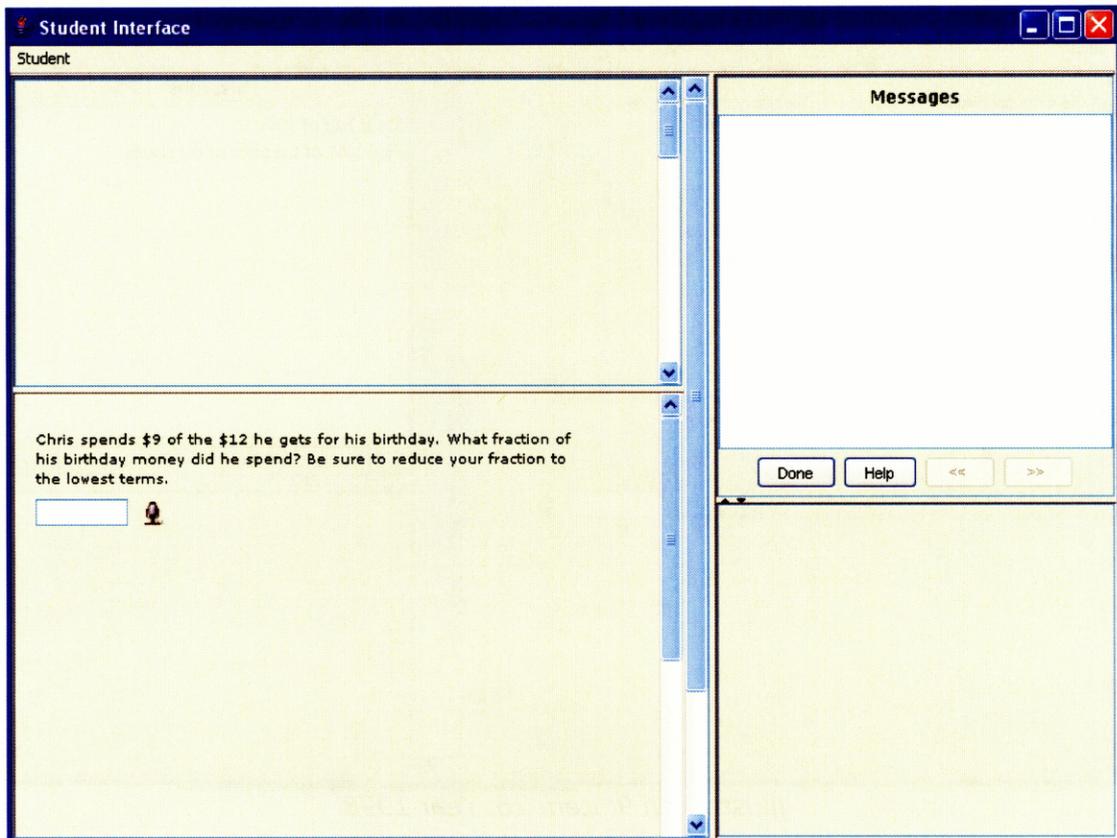


Illustration 10: Item 27, Year 1998

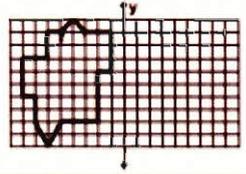
Student Interface

Student

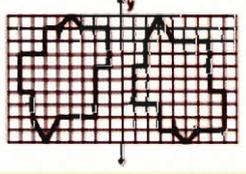
**Messages**

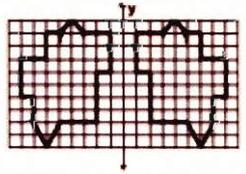
The reflection of an image is the mirror image, meaning the reflected image would appear as if you were looking at the original in a mirror.

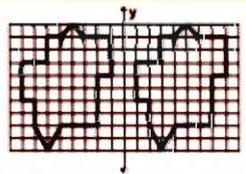
Done Help << >>



The figure shown above is to be reflected over line  $y$ . Which of the following shows the figure above being reflected over line  $y$ ?







done

Illustration 11: Item 29, Year 1998

Student Interface

Student

The table below shows the number of points that Luna scored in his last 10 games of the season. Find the mean number of points scored by Luna

Player	Points scored in last ten games
Luna	22,17,23,8,24,24,22,20,18,22

Lets break the problem down some. What is the definition of mean?

- Middle number of a set
- Number occuring most often in a set
- Average of the numbers in a set

Messages

The mean is the average of the numbers in a set.

Done Help << >>

Illustration 12: Item 30, Year 1998

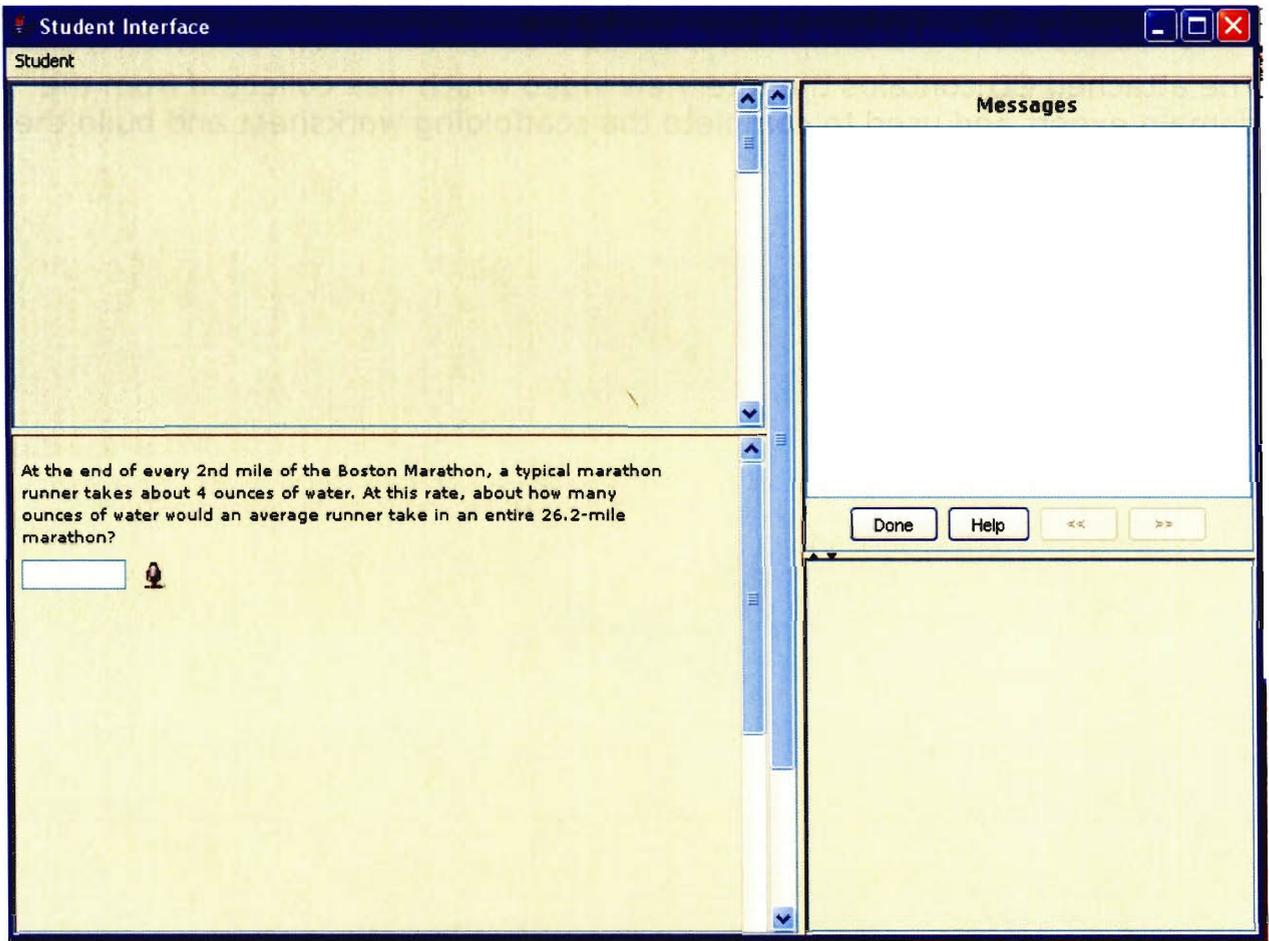


Illustration 13: Item 31, Year 1998

## **Appendix D – Interview Videos**

The attached CD contains the interview video which was collected from the domain expert and used to complete the scaffolding worksheet and build the assistment.

Appendix not included  
in original submission

# IQP/MQP SCANNING PROJECT



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