Game-Like Elements

Exploring the Use of Narrative in Mathematics Education

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ABSTRACT

Generating student interest in academics has always been a challenge, and the advent of electronic entertainment has not made this challenge any easier. However, by incorporating the engaging elements of these electronic systems into traditional teaching methods, educators could better attract their students to academic content. Using two sets of surveys, we developed a prototype intervention to gauge student interest in the use of one such element, narrative, to teach middle school level geometry.

I. Introduction

Humans have been telling stories since before the invention of language. From crude paintings in cramped caves to complex reliefs engraved into enormous pyramids, narratives have always been an important part of human culture. Stories are often used to simultaneously entertain and inform. Many early societies relied on oral tradition, using myths, parables, and fables to pass an entire generation's knowledge to its children. Even after the development of writing, the tradition was famously carried on by Aesop, Jesus, and the Brothers Grimm.

Even in the modern day, stories are still used in educational settings. Many math and physics textbooks include "word problems" nestled next to graphs and equations. These questions present the information needed to solve them as a miniature story rather than mathematical notation. Word problems can be especially helpful in understanding math concepts, as they connect mathematical abstractions to real-life situations, making the questions accessible to more concrete-minded individuals. They are normally designed to present relevant information as quickly and as simply as possible, and are usually no more than a few sentences detailing the mathematical predicament. This simplification removes many of the essential elements of a good narrative, often leaving the described situations bland and uninteresting.

But what are the elements of a good narrative, and what could their presence add to an educational story? This is what we wanted to find out.

We were interested in discovering the effects of a full narrative on the educational benefits of word problems. To this end, we created an interactive narrative as a proof of concept. The intervention was a series of word problems, connected by a consistent plot and characters. Ostensibly, the problems test middle school students on their geometry skills, but their dual purpose was to test the validity of using narrative elements to enhance student engagement in mathematics. In order to gauge their interest, students who completed the intervention were directed to provide feedback in the form of a post-test survey. The survey asked students about their likes and dislikes from the intervention, as well as their thoughts on specific aspects of the questions. Not only did this allow us to evaluate the effectiveness of the intervention as a whole, but also the effectiveness of the individual narrative elements.

II. Background

2.1 Characteristics of Middle School Students

Perhaps the greatest challenge to overcome in teaching pre-teen/early adolescents is understanding the complex nuances of their behavior. The early teens is often an age teachers and parents alike misunderstand. A common stereotype about middle schoolers is a perceived maturity level comparable to younger children combined with a cocky and arrogant attitude typical of teenagers. As such, middle school students are typically viewed as an unruly and difficult to teach group. However, these stereotypes are simplistic and only scratch the surface of a young person's complex and developing social life. To educate middle schoolers effectively, the true difficulties of the age group must also be brought to light.

Also of note are the behavioral changes as students progress from early childhood to young adulthood. Most adolescents of middle school age are at the height of puberty, which can effect behavior from both biological standpoints, and social standpoints due to new ways to be self conscious (Morgan and Huebner, 2009). Contrary to common belief however, aggressive tendencies and snarky behaviors associated with middle schoolers are not only due to increases in hormonal levels. Instead, they can be often attributed more directly to factors such as a sleep deprivation and the inability for adults to relate to middle school difficulties. Adolescents need more than nine hours of sleep due to biological

changes, but are often sleep deprived due to societal obligations (National Sleep Foundation, 2013).

Middle school children can also be self conscious due to their age range. It is critical to remember that adolescents are not young children and do not think like young children. In terms of cognitive development, early adolescence marks greater developments of abstract thinking in children. Instead of being concerned primarily with concrete aspects of the world around them, middle schoolers begin to think inward about themselves. (Morgan and Heubner, 2009). One mistake educators can make is using the same approaches with early adolescents as with younger children; an easy but fatal mistake in terms of building respect towards students.

2.2 Reading Habits

Before creating something meant to be read by middle schoolers, it is necessary to explore their reading habits. Understanding what middle school aged students like and dislike in books and narratives helps create our own tailored narrative, while knowing what drives some to dislike books and reading helps avoid the same issues in our study.

The first step in such an investigation is to create a solid definition of reading. This may seem unnecessary – after all, reading is just the act of comprehending the written word. However, the ability of a student to read the label on a soup can or a text message from a friend is not as relevant to this study as his or her ability to read a novel or a magazine. As such, reading as it is discussed in this context is the ability to read and understand the

contents of non-trivial publications. Such publications include novels, short stories, news articles, academic papers, and other persuasive or informative writings, either in print or electronic. Other forms of written language comprehension, such as reading a text message, a Tweet or Facebook post, a label or caption, or another trivially small piece of reading material will not be considered. This is largely because we wish to examine the effects of narrative in a game-like learning environment rather than the overall effects of reading in the same environment.

What kinds of “non-trivial publications” do middle schoolers enjoy reading? According to research at the University of North Carolina, middle school students prefer fiction books, be they novels or short stories, over any other form of reading. Nonfiction books came second in approval, but by a large margin; about 30 percent more students professed an interest in fiction over nonfiction (Smith 2009). These findings are supported by several lists of the “best” books for the age group, some of which were compiled by middle school students themselves and are all overwhelmingly populated with fiction novels (Scholastic 2013, Goodall 2009). Further study at the University of Maryland shows that middle schoolers are generally uninterested in what was defined as “information books”, books with the express purpose of teaching a topic such as math or science to the reader. Few students found reading such books for class interesting, and almost none admitted interest in reading them for pleasure (Guthrie et al. 2009).

These characteristics are all descriptive of students who would identify themselves as “readers”. Students who would not describe themselves as readers typically display different traits. Kylene Beers (1998) preformed a study that included a number of interviews

with middle school aged students, focused primarily on each student's decision to read or not, and the reasons for that decision. Beers noticed a pattern of responses in the students' answers and categorized them into five groups: Avid, Dormant, Uncommitted, Unmotivated, and Unskilled Readers. Avid and Dormant readers typically enjoy books and like being labeled readers, while the last three groups typically enjoy activities besides reading and dislike the label "reader". The main difference between the two subsets, Beers argues, is that readers see and understand the use of reading as a source of entertainment, where non-readers see reading as nothing more than a means of conveying information and cannot connect with the text on an emotional level.

Beers went on to enumerate the kinds of reading-related activities readers and non-readers enjoyed. Readers enjoyed choosing their own books, going to the library, and sharing and discussing books with their friends. Non-readers enjoyed having books read to them, reading books with illustrations or doing art activities to aid in the visualization of the story, and generally preferred nonfiction material like magazines and handbooks over novels.

Multiple studies have discovered differences in reading habits between genders as well. According to a study by The Program for International Student Assessment (PISA), on average, girls enjoy reading for pleasure more than boys. World wide statistics indicated that fifty-three percent of boys and seventy-three percent of girls read for enjoyment (OECD 2012). Estonian researchers Uusen and Müürsepp (2012) came to similar conclusions for their native country.

As part of a study on serialized books, middle school students in Ohio reported their favorite book series (Rakas 2009). Preferences between males and females were largely different, though some exceptions existed, including Harry Potter (J. K. Rowling), Shadow Children (Margaret Peterson Haddix), and The 39 Clues. Series like Artemis Fowl (Eoin Colfer) and Redwall (Brian Jaques) were only mentioned by males in interviews, while series such as the Twilight Saga (Stephanie Meyers), Junie B Jones (Barbara Park), and American Girl were only mentioned by female readers. It seemed that male readers were unwilling to read (or admit to reading) books considered "girly", though female readers had less compunctions about reading primarily boy-oriented books.

2.3 Interest in Characters

The most important aspect in designing a main character for any audience is relateability. A study in North Carolina schools surveyed students on the kinds of people and characters about which they enjoyed reading. The top responses included "People my age who have done cool or amazing things" and "People/characters like me" (Smith 2009). Middle school students, like most readers of any age, seem particularly interested in characters they feel they can relate to, though their limited experience narrows their interest to other children their age.

The popularity of novels aimed at this demographic, such as J. K. Rowling's *Harry Potter* series and Suzanne Collins' *The Hunger Games*, attests to this. However, this does not necessarily mean characters of a different age group cannot work in a narrative geared towards this target audience. Looking at the list of popular titles for a middle school target

audience by Scholastic, Inc., some top selling titles feature older teens or historical figures (2013). Nevertheless, most of the titles in the list feature characters close to in age, or only a few years older than, middle school children.

If our goal is mass appeal, the problems of designing main characters any person can relate to becomes apparent. Should the character be male or female? What are our audiences cultural backgrounds and expectations? What is their age and educational experience? Thinking about these types of questions can help content creators narrow down their target audience to a specific group, but they demonstrate the problem of mass appeal: the more narrow you focus , the more apparent it becomes that cultural differences and expectations are difficult to overcome. A rural community in the midwest will have very different cultural and educational experience than a coastal city such as New York City.

Trying to build a main character with true mass appeal is thus impossible. As with any umbrella demographic divided by age, the “tween” age is diverse and cannot be simplified into a simple mold. Groups of people can always be broken down further into deeper splinter groups of differing interests. Appealing to as broad an audience as possible, even within a targeted demographic will never be completely achievable. But there is a unique aspect of interactive stories that allows this hindrance to be partially overcome.

Digital and story-based games can be designed so the character being controlled is the player him or herself. Many games also allow users to play as their personal in-game avatar. Several modern video games use this approach to enhance player immersion in

the game's imaginary world. Several games such as Nintendo's *Wii Sports* allow players to create custom characters resembling themselves. Other games like Mojang's *Minecraft* take player insertion a step further by using a "first person" viewpoint where the player can look through the eyes of their avatar.

In literature, the term for narratives referring to the reader are called "second-person narratives." Instead of using "I" as the primary pronoun, "you" is used in its stead. Interactive stories such as the *Choose Your Own Adventure* book series and text adventure games like Infocom's *Zork* and *Trinity* are examples of second-person narratives.

2.4 Narrative Genre

"Genre" has a different context when speaking about games and other interactive media. In the context of interactive applications, a genre refers more to a style of play or a type of game. For example, "racing" as a game genre usually refers to any game involving driving a car, regardless of realism or tone. In literary terms "genre" refers to similarities across stories that allows for classification. It describes common literary themes as opposed to mechanical elements. This distinction is worth noting due to the nature of our IQP.

We want our narrative to appeal to as broad an audience as possible, so it is important to carefully research genres middle school students would find most interesting. Observing popular titles, some basic genres that are familiar to and often popular with middle school readers include Action, Adventure, Mystery, and Fantasy. Top selling books

aimed at the middle school demographic generally fall towards the unrealistic and fantastical side of the spectrum (Scholastic 2013, Goodall 2009). However, the results of a study in middle schools in North Carolina seem to indicate an interest in realistic fiction – that is, made-up stories about characters, places, and situations that could believably exist in reality (Smith 2009).

It may be useful to better define these individual genres to understand why middle school students enjoy them. Action is a series of frantic and challenging sequences. Often they are physically violent, but don't necessarily have to be. Action can range from martial arts fighting to professional racing. Adventure usually involves some sort of journey of the protagonist, exploration of an unknown land, and dangerous experiences. Mystery involves at least one character attempting to figure out an unsolved or ambiguous problem. Fantasy is an alternate reality, a world invented by the imagination not strictly bound by the laws of our nature (Merriam-Webster, Inc. 2013).

Based on the familiarity of these genres and prior research indicating their interest amongst middle school aged children, we decided to use them for the basis of our study game. Details of our results on testing favored genres and how we built our game can be seen in our design section.

2.5 Interest in Series

Since book series are popular among teens and preteens today, we want to discover what sparks middle school readers' interest in them. After all, the most engaging

narratives are the ones that can keep readers hooked across multiple books. We want to find the techniques that keep students engaged and embed them in our own work.

In 2009, a study was performed by selecting participants from suburban middle schools in northwest Ohio (Rakas 2009). The subjects were spread between fifth and eighth grades. In the study, interviewers asked students if they identified themselves as readers of serial books, and conducted attendant interviews based on middle schoolers' responses to the question. The results indicated that serial books were generally enjoyed by middle schoolers, largely due to their continuous nature. Many serial book readers believed that serial books provided accessible reading experiences, promoted a mix of socialization and literacy, encouraged them to read for pleasure, and increased their reading amount and reading skills. Serial book readers in the study reported that they enjoyed finding out more and more about characters as series progressed in order to get much closer to them.

Many serial book readers enjoyed talking about series with peers, teachers, and family members. Some students in the study regarded this discussion as the main benefit of reading book series. These findings demonstrate that middle school students develop intrinsic motivation by interactive communication with individuals around them. The study also stated that the majority of middle school students tended to find new serials to read on their own. Students usually chose books according to their appearance on the cover and the brief descriptions on the back.

2.6 Learning Styles

Statistics show that some students learn some things quicker than others, and among many reasons, including differences in intelligence and learning rates, learning style is considered an unavoidable factor (Hmelo-Silver 2004). Problem-based approaches to learning have a long history in education. Problem based learning, or PBL, is “focus, experiential learning organized around the investigation, explanation, and resolution of meaningful problems” (2004). PBL skills are usually developed in a cycle, as shown in the figure below, and the instructor acts as the facilitator to guide students throughout this cycle (2004).

In PBL, students work collaboratively in a small group to solve problems presented in different scenarios and then reflect on their experiments. This helps students become active learners due to its real-world problem scenarios and improves students’ responsibility towards their own learning development. In general, PBL is designed with some important goals to help students “construct an extensive and flexible knowledge base; develop effective problem-solving skills; develop self-directed, lifelong learning skills; become effective collaborators, and become intrinsically motivated to learn” (2004). There are some research conducted with K-12 populations and much of the research included case study and pre-post test (2004). These designs were planned carefully to make them effective in 50 minute class periods. The results suggested that PBL promoted students to apply knowledge into the take actions since it is an active and transferable learning that has a large potential to motivate students.

2.7 Prior attempts at integrating math with narrative

The concept of integrating math into stories is not new. There have been many previous attempts at such integration, especially for young learners in elementary school. As with our project, their intent was for the fun and interesting elements of the stories to motivate students to complete and comprehend the educational content integrated with the stories.

One of the most famous forms of narrative are picture books. Picture books are most popular among elementary students since they help children visualize. These picture books can also help students learn by verbalizing or visualizing abstract concepts, particularly in math. For example, “Sir Cumference And The First Round Table”, by Cindy Nueschwander and Wayne Geehan, used stories and pictures to teach elementary kids geometry (Osborn 2001). It attracts the kids with beautiful artwork and interesting storyline. The math content was minimal compared to the narrative and pictures, since these story books were intended for young kids. This attempt was successful since many kids enjoyed it and several sequels were published.

In the ‘Monkey’s Revenge’ narrative game, a coordinate geometry tutor containing narrative, sensory stimuli and immediate feedback, the authors created four different versions of the game, each containing a different combination of game-like-elements (Rai 2010). The versions containing the game-like elements proved to increase the learning gain when compared to the basic tutor version, which did not contain any game-like

elements. The researchers concluded that the narrative and visual elements improved students' enjoyment and satisfaction, but could not make a conclusion about the learning gain since the pretest and post-test showed no significant gain across the student population. The students were not pleased with the time given since they did not have enough time to solve the problems. The visuals and the narrative did not seem to impose cognitive overload, which is important since this is the biggest trade-off between game elements and learning.

In a previous Interactive Qualifying Project, the project researchers used a narrative with fantasy in an effort to interest students in educational material (Suarez et. al. 2012). They implemented geometry problems for the middle school students into the story and it was quite successful. Their narrative had four stages with increasing level of difficulty. It was concluded from the surveys at the end of the narrative that the students enjoyed the story and the math content in it. The proper integration of math into the story kindled the students' interest in playing the game, and increased their learning in math by fostering practice with the math problems. However, the students indicated that some of the math problems were too difficult to solve, and, as with "Monkey's Revenge", there was not enough time to complete the problems. The results also indicated that some of the problems were confusingly worded and needed to be simplified to help the students better understand the questions.

2.8 Narrative and Learning

Students are often faced with motivational difficulties in normal learning activities in school due to the abstract nature of the educational contents. Studies have shown that the intrinsic motivation in students decreases from 3rd grade through high school (Cordova & Lepper 1996). Researchers have conducted experiments to find ways to improve intrinsic motivation in students. Cordova and Lepper suggested that when abstract learning materials are presented with meaningful contexts that students can relate to, it will invoke intrinsic motivation in students. They also stated that students learn better this way and even remember material better.

People have innate abilities for crafting and understanding narratives. Therefore, contextualized educational content is known to support learning (Mcquiggan et. al. 2008). Narrative elements not only launch novel perceptual, emotional, and motivational interests, but also make a connection between the narrative and educational content in young learners.

Narratives help students learn by providing elements of engagement in learning including comprehension, curiosity, presence, challenge, and goal. Although there is a popular view that there is a trade-off between learning and engagement, the Crystal Island experiment showed that increased engagement improves learning outcomes and problem solving (Rowe et. al. 2011). Crystal Island is a narrative-based game for middle school students to improve learning in Biology. The experiment was conducted with 153 middle school students and the researchers found a positive correlation between learning outcomes and increased engagement instead of finding the two contrasting. However, due to the complex nature of engagement, these elements can distract the students and disturb

the learning gain. In order to optimize this gain, the narrative needs to have a perfect balance between the educational content and the engaging elements. A story-based game for learning should contain interesting, suspenseful and entertaining story to motivate the students, but if it becomes too complicated it may overload the learner. The story should be challenging but not too stressing so that the learners will enjoy both the game and the educational content (Gobel et. al. 2010).

Cognitive overload occurs when the learner's intended cognitive processing exceeds their available cognitive theory (Mayer & Moreno 2003). According to cognitive overload theory, humans have unlimited long-term memory but severely limited working (short-term) memory. Due to the limited nature of a person's working memory, learning is ineffective if the required cognitive load exceeds their available cognitive load (Cooper 1998). Therefore, in order to avoid the cognitive overload as much as possible when designing narrative story to improve learning, it is important to make the story easily comprehensible to the learners by using clear wording and avoiding complicated stories that would require too much focus and memory to follow.

III. Design

According to the previous studies that we found, the game elements are proved to be effective in helping the students learn by invoking the interest level of students in the educational content. Monkey's Revenge, Crystal Island, and previous IQPs inspired us to create a narrative intervention. We were interested in studying how elements of narrative help students learn, and how best they could be integrated into educational content. In order to best interest students in using and learning from our program, we wanted to create a narrative that contained the elements that middle school students would be most interested in.

To design a narrative for middle school students, we thought it would be best to first investigate the middle school students' nature in terms of their reading habits, favorite kinds of books, and favorite characters. We explored previous research in the area, but decided to base our narrative on the interests of the students we were most likely to work with - those enrolled in Worcester public schools. We created a survey to examine these features and distributed them to students in the Worcester area. We then developed a narrative from the responses obtained from the surveys. We also put our story concepts into the survey and tested the students' interest in each of them. We circulated two iterations of this survey, the first on paper and the second electronically, to get a good idea of what elements to include in our design. Our final narrative was derived from the story concept that achieved the highest rating in our surveys.

Our program contains a pretest and post test aside from the actual intervention. The pretest is designed to test the knowledge of the students about the kinds of math problems presented in the narrative. The post test is a survey to determine the students' interest in our narrative, how the students feel about effectiveness of the narrative, and their suggestions for possible improvements.

We chose to create a narrative around 7th grade geometry. We chose it primarily because the concrete concepts presented in geometric problems are easier to integrate into a narrative than the more abstract ideas presented by algebra. Additionally, pictures and diagrams are integral to geometry. We thought that by combining our narrative with pictures, we could command more attention from the students. The initial survey results indicated that students do not like word problems, so including diagrams would help maintain the students' interest in the narrative.

We decided to use the ASSISTments platform, an online browser-based tutoring program, to host our narrative. ASSISTments is designed for online tutoring and assessment, and is used by teachers to assign homework, quizzes, and practice sets. It is utilized primarily in the Worcester area, but is also used in other schools across Massachusetts, and in other states like Maine, New Hampshire, and Montana. We anticipated that ASSISTments would make it easier for us to distribute the narrative and analyze data after its deployment. It also allowed us to include hints and breakdowns of the problem sets in the narrative. We decided to use an existing website to host our narrative rather than creating our own in the interest of time. The ASSISTments website can be

found at www.assistments.org.

IV. Methodology

Methodology Overview

Our design was carried out in two phases. The first phase was the initial surveys where we investigated the middle school students' reading habits and the second phase was the actual narrative intervention. The initial surveys were distributed to middle school students in different grades: grade 6, 7 & 8 to examine their reading habits. The purpose of these initial surveys was to give us an idea of a narrative that we could create to have an engaging experience for the middle school students. We created two iterations of the initial surveys. A second iteration was modified based on the answers from the first iteration of the survey. The first iteration was carried out on papers in a classroom environment and the second iteration was carried out in a web-based system ASSISTments.

The second phase was the narrative intervention, and designed to be carried out in the ASSISTments Online Tutoring program. The intervention was designed to contain hints of varying interactiveness for each problem, should the students encounter difficulty solving the problem. A pretest before the narrative intervention served to collect information about the student's prior knowledge of the subject included in the narrative. After the narrative intervention, a post-test assessment was included to gauge how much the students enjoyed the narrative and to get ideas for possible future work.

4.1 Surveys

Our initial surveys were designed to comprehensibly determine the reading interests of the students. The questions primarily measured reading habits, such as the average number of hours spent reading every week, favorite book series, and favorite genres of literature, as well as the type of material students primarily read. This allowed us to determine the best choice for the media and structure of our narrative.

4.1.1 Survey – Iteration 1

Iteration 1 was the first attempt to complete the first phase of our surveys. This survey and its later iterations helped us determine a design for our narrative. It was distributed via printed sheets to 6th, 7th and 8th grade students at local middle schools.

Population Summary

Our subjects were intended to be exclusively of middle school age. The intent of the narrative was to appeal across as many demographics as possible and especially across genders within the junior high school age. With the help of middle school teachers local to the Worcester area, this iteration was distributed to a total of 78 middle school students. The population includes 42 6th grades, 25 7th graders, and 11 8th graders. Overall, the ratio of boys and girls are about the same. Limiting our distribution to mainly one state might skew the results somewhat due to different educational standards and slight cultural variations across the United States. Future iterations were distributed digitally in an attempt to correct this and allow some participation from across the country.

Results

We analyzed across three portions of our population; one section covered the boys who took the survey, another, the girls, and the third the entire population. We did not analyze the data with groups based on grade, as there were not enough responses from each grade to warrant such a separation.

The first question asked students about their favorite type of reading, intending to ask about the format of the reading rather than the content. Possible results included Comics, Novels, Fiction, Nonfiction, Short Stories, Magazines, and Newspapers. Although there was an option for “Other”, the students used it infrequently. Those that did answer “Other” often mistook the question for its follower, writing in their favorite genres for their preferred type of reading. During analysis, we included these write-ins with the results for the next question. Students were allowed multiple answers to this question, so we expected some overlap.

As a whole, the students preferred reading material featuring fiction, with nearly 70% of responses indicating such an inclination, with an even spread between boys and girls. Magazines, comics, and novels were popular reading formats, each with support from about a third of the students. Of these, boys tended towards comics, while girls were split between novels and magazines, with a slight lean towards the latter. Newspapers were by far the least popular, with a mere 8% of students reporting interest.

The second question regarded the students’ interest in individual genres, asking

them to choose their favorite from a list. In addition to a now oft-used “Other” option, the provided responses were Adventure, Mystery, Action, Nonfiction, and Fantasy. Though students were instructed to choose only one answer, many chose more. Even so, we considered all answers during the analysis.

Adventure, mystery, and action each received a nearly equal number of responses, with a little less than a third of all students showing interest in each. Between genders, there were equal responses for adventure, but mystery held more appeal for girls, and action more appeal for boys. Fantasy did not fare poorly, with about a quarter of the students showing interest. Nonfiction, however, had an abysmal showing, with only one response. Of the half-dozen write-in responses (some of which were pulled from the first question’s write-in), only one answer received more than one or two replies. Realistic Fiction was input by seven different students, mostly girls, which made up about 10% of the responses. Some other genres that the students mentioned were historical fiction, science fiction, horror and mythology.

The survey also included four “Yes or No” questions. The first, “Do you like word problems?” met with a resounding no. Two thirds of the responses were negative, and though neither gender responded in the affirmative, girls seemed more disposed towards word problems than boys. The second question asked “Do you read book series?” This met with more positive responses, again with more girls answering to the affirmative, though with not as large a gap between the genders. The most popular series mentioned was Suzanne Collins’ *The Hunger Games*, followed by a tie between *Percy Jackson & the*

Olympians (Rick Riordan) and *Diary of a Wimpy Kid* (Jeff Kinney).

The third and fourth questions asked about the student's character preferences in a story. Specifically, the students were asked whether they liked a hero character with a "side-kick" and whether they preferred one "main enemy" against the hero. Despite several non-responses, students generally expressed non-interest in side-kicks and interest in a single antagonist, with little difference between the genders.

Students were also asked how often they read, and were instructed to give their best estimate as to the number of hours per week they spend reading. The average time spent was about 3.3 hours, or approximately 3 hours and 20 minutes, per week.

The final question presented three simple story ideas to the students and asked them to rate their interest in each story on a 1 to 5 scale, with 5 denoting the highest level of interest. Story A featured alien abductions, Story B a manhunt for a missing person, and Story C the inner workings of various amusement park rides. Story A received an average rating of 2.2, story B held a rating of 3.2 and story C 2.6.

The complete question set can be found in Appendix A.

Observations and Discussions

The main focus of our data analysis was gender disparity, determining if there were any interesting differences between boys and girls. Regarding favored story genres, our results showed that Mystery and Action were the most popular, followed by Adventure and

Fantasy. Since we allowed multiple answers to this question, some students chose 2 or 3 genres to be the most exciting. As such, we decided to do a coverage analysis on the responses to find out which blend of genres would appeal to the most amount of students.

We carried out the coverage analysis for the top four genres with sets of two genres. The purpose of this coverage analysis was to find out a combination of two genres that will appeal the most population. Since most popular books contain a combination of two genres, we decided that we could easily implement a narrative with a combination of two genres. In the coverage analysis shown in **Figure 1**, the Venn diagrams are used to show the results of coverage analysis. Each of the Venn diagrams shows the number of students who liked only a particular genre, number of students who liked both and the total number of students who liked either of the two genres. As can be seen from the diagrams, we concluded that the set of Mystery and Action appealed the largest population. This result showed that a good balance between the preference of boys and girls which were Mystery and Action would appeal the largest population.

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Figure 1: Coverage Analysis using Venn Diagram

Moreover, the three most popular series books mentioned by the students have a teenage as main characters and the genres are action & adventure, fantasy & adventure and comedy. Besides comedy, all other genres score high in the second question. Interestingly, the most popular series are not Mystery genre which could be due to the popular mainstream nowadays. The movies for all these series books have been released recently and gained popularity among teenagers which made the books popular too**.** The students who enjoyed the movies might also read the books since the books usually contain more details and allow imagination for the readers. However, having a teenager as a main character is consistent with the literature review in the previous section which led us to create stories with a teenage main character.

When asked how many hours they spent reading each week, most students responded between 1 to 3 hours. The average number of hours of reading for these students is 3.33 hours. However, there were some outliers; 2 students reported reading more than 20 hours per week. These students might have misinterpreted the question, so we calculated the average without these outliers and found the average was 2.72 hours. Boys reported a lower average time than girls, with about a 45 minute difference per week.

For our story ideas, story B was apparently the most popular, and stories A and C had about the same ratings. This supports the students' favored genres, as story B contained more elements of the mystery genre than either of the other stories. Stories A and C received more interest from boys and Story B received more interest from girls, again reflecting the results of the favored genres, which indicated the girls had a higher interest in mystery than the boys

Planned Improvement

After reviewing the results of our first survey, we determined several things needed to be changed before releasing it to a larger population. First, the format of the questionnaire needed to be changed; it is difficult to obtain a large number of responses using hard copies of the survey. Instead, we decided the survey needed to be moved to a virtual environment, readily accessible via the Internet. For this, we planned to use the online tool ASSISTments, provided by Worcester Polytechnic Institute.

Additionally, we realized that the wording of several of our questions was potentially

confusing to the students, and we resolved to make the questions more clear. We decided that removing extra instructions such as “choose only one” would help clear up confusion. However, this would require some restructuring of the survey.

Finally, we decided to change the story ideas included in the next survey. Using the information gathered from this iteration, we hoped to make more ideas that would appeal to a wider range of students and hopefully score better than our initial ideas. One potential problem we found with story idea C, the lowest rated story of the three presented, was that its description was longer than the other two stories. Students might not have been motivated to read the long description and could have given a lower rating based on a quick scan. Therefore, we decided to make sure the description of stories in future surveys were a uniform length.

4.1.2 Survey – Iteration 2

Iteration 2 was the second attempt to complete the first phase of our surveys. This survey was a revised version of the previous survey and was circulated to another small group of 7th grade students via online distribution, described below.

Changes from Iteration 1

Considering our limited time and high volume requirements, we decided to change

the format of the questionnaire from a printed sheet to an online assessment so that we would be able to distribute it to a larger group of students. An online tutoring program, ASSISTments, was utilized to implement the survey. ASSISTments is a web-based system for mathematics, that can also present survey questions.

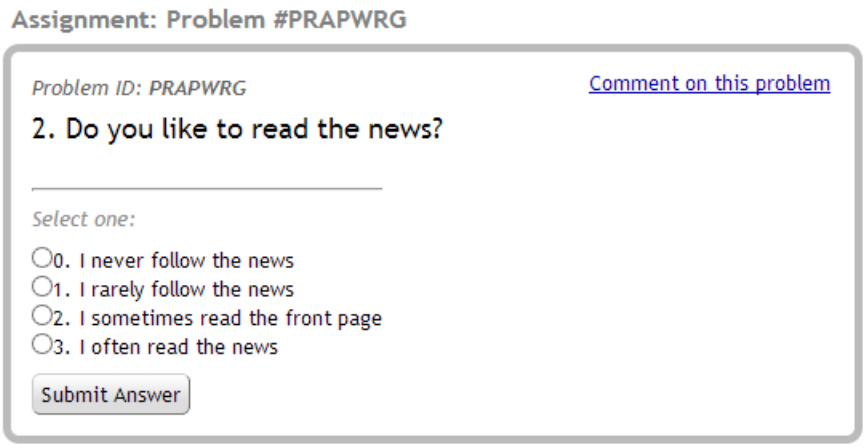

Figure 2: Screen shot of a survey question on ASSISTments

Major changes to the survey itself included the wording and format of some questions, as well as a new introductory paragraph for the survey. We decided to change the wordings of questions that we thought were confusing to the middle schoolers, particularly the question regarding preferred “genre” of reading. Instead, we decided to ask about the students’ “favorite kind of story”, though the possible responses, with one exception, were the same. Given the popularity of realistic fiction as a write-in response in the first iteration, we decided it was appropriate to add it as a standard response in the second.

We also overhauled the question on students’ preferred reading material, such as

magazines, comics, and novels. In the first iteration, the question asked, “What types of reading do you like?” We provided a cluster of different reading materials and asked the students to circle all the responses that applied to them. However, we were not able to determine the degree of liking to different genres. We decided to create individual questions for each reading material and asked the students how much they liked each one. For instance, one question asks “Do you like to read magazines?” to which the student could answer on a scale of one to three. We believed this format would provide better knowledge about readers’ preferences across all reading materials.

We decided to eliminate stories A and C, since they did not rank well in the previous survey, and to keep story B as a control in the new survey. Based on the results of the first iteration, we came up with four new story ideas, using the most popular genres. These stories revolved around:

A. A famous detective solving mysteries
B. Adventurous children lost in a magical cave
C. A wizard’s journey to find his magic wand
D. A floating island powered by failing machines

After some review, we realized that we needed to change most of these stories. Story A needed to be narrowed down to a more specific story line, as it was very broad. Story C lacked a side kick like the wizard’s apprentice or an antagonistic role, and was again deemed too broad. Story D, even after thorough simplification, still seemed too complicated for middle school students due to its abstract background, and had striking

similarities to the least popular story in the first iteration, the theme park mechanic. Story B, however, appeared similar to storylines from the classic “choose-your-own-adventure” series.

Considering the coverage analysis done in the first survey, we decided it was best to try and include multiple genres in each story. To this end, we combined story A and story C, as the combination of mystery and fantasy elements would perhaps be appealing to the middle schoolers. We also re-worded the magic cave story and the missing persons story from iteration one to include more elements of the popular genres from the previous survey. Finally, we ensured the description of each story had a uniform length, to encourage students to read each of the descriptions with equal attention. The following briefly described our improvements in story ideas along with the corresponding genres:

E. A detective helps a wizard to find his lost magic wand (Mystery and Fantasy)
F. A group of kids adventure to a local haunted cave (Action and Adventure)
G. A mission to find your suddenly disappeared twin brother (Mystery and Adventure)

After implementing our planned changes, we uploaded the survey to ASSISTments and began searching for a teacher willing to assign the questionnaire to his or her students. The complete question set is included in Appendix A.

Population Summary

We decided to release this survey to another pilot group of middle school students to find problems with the survey. With help from ASSISTments education specialist &

project manager, Cristina Heffernan, this iteration was distributed to a total of 74 7th grade students from a Worcester-area middle school. Among these students were 33 boys and 41 girls. Similar to iteration 1, iteration 2 was also restricted to a single school district, which could skew the results when considering the whole population of middle school students across the country. As the medium of the survey was changed to the Internet, we expected future releases to reach students from other states, to reduce the potential bias that could result from the limited area of study.

Results

As with our first iteration, we decided to split the girls and boys into two different data sets. The most striking difference between the two genders was how they reacted to different genres. The girls liked Mystery the best at thirty-four percent, with Fantasy at a fairly sizable second at 20 percent. Adventure followed at seventeen percent and Realistic Fiction at ten percent. Only a negligible quantity, about five percent, of girls liked action. In contrast, boys overwhelmingly liked action the best at 36 percent. Adventure followed at 15 percent and Fantasy at 12 percent. Mystery and Realistic Fiction tallied in at 9 percent each. The results between the girls and boys nearly mirror each other. This may pose a serious challenge in targeting our narrative to both genders.

The genders were less divided on preferred type of reading material, with the exception of one category. Girls overwhelmingly read more magazines compared to boys. This might be explained by the higher saturation of magazines targeted for teen and

pre-teen girls compared to boys of the same age. Other types of reading were closer to equal among the genders. News was read only moderately by both groups. Short stories were also mostly rated a “two” on the frequency scale by boys and girls, both at about 60 percent. A higher percentage of girls, about 24 percent, very frequently read novels, compared to only 12 percent of boys. The overall data for types of leisure reading material suggests boys are less likely to read compared to girls.

Other results when split between the two genders were less dependent on gender correlation. However, there were a few outliers who responded with unreasonably high numbers and there were some non-responses. The average time spent on leisure reading was close to 2.5 hours for both genders considering zero for non-responses. The median was quite different between boys and girls. The median for girls was 1.25 and that for boys is 0.5. These medians did not count the non-responses and the low medians were due to many zero responses even with a few outliers. Fiction was also preferred over non-fiction by both genders, and word problems were universally reviled. Including a side kick in the story was rejected by a majority of boys, as well as a slightly larger majority for the girls. Featuring a main villain, however, was still popular with large majorities for both genders.

Due to our small sample size, some data remained unclear. It was difficult for us to determine, due to the small sample size, which of the three story ideas was the children's favorite. Our margin of error was very high for these results and should not be trusted as absolute data. Story A consistently placed dead last throughout the pilot survey. In the previous iteration, story C seemed to be the most popular. This trend continues for this

survey, but story B placed in a close second.

Observations and Discussions

The data for this survey was also analyzed based on genders, as the first set of surveys showed a measurable disparity between boys and girls in their preferences for different genres. The results from the second iteration showed similarly to the first iteration, with small discrepancies.

The top 4 genres from the second iteration were the same as from the first iteration: Mystery, Action, Adventure, and Fantasy. Although in the first iteration, the top 2 genres received the same ratings, the ratings were more spread out in the second iteration. The fact that there were more girls than boys in the second iteration might explain this difference, given the two genders' different preference in story genres. In keeping with the results of the first survey, girls preferred Mystery and Fantasy and boys preferred Action and Adventure. Therefore, it is likely that the genres preferred by girls, such as Mystery and Fantasy, scored higher overall than the previous survey.

From our data analysis, one thing we needed to consider was the number of non-responses. About 20% of boys and 9% of girls did not respond to this question. We concluded it was possible that some students did not have a favorite kind of story, since they responded to almost all questions in the survey except for story genre preference and hours of reading. We decided to include this option in future surveys to find out. One more interesting fact was the preference of Adventure. Although it was the second most

preferred genre by the boys, a larger percentage of girls, about 17%, favored Adventure. Only about 15% of boys favored this genre, which could be due to a higher non-response rate.

We analyzed the hours of reading responses in two different ways since there were a good number of non-responses. First, we calculated the average by treating the blank as non-responses and second by treating them as “0”s. The difference was about 48 minutes. From the analysis of different genders, the results showed that boys read about 30 minutes more than the girls. The average hours of reading overall were about two and a half hours which was about the same as the result from the first iteration.

For the Yes/No problems of word problems, having side kick and main enemy, the results were similar to the first iteration, except for having a side kick. Unlike in the first iteration, most students from the second iteration did not prefer a side kick in the story. One problem we noticed with these Yes/No questions was the fact that they were presented consecutively in the survey which would have led some students to choose random Yes and No’s.

Lastly, for the story ideas, most students seemed to favor Story C the most which was a modification of the most popular story from the 1st iteration. All the story ideas were based on the most popular genres. The Story C has the elements of Mystery, Adventure and Action which reflected the results from the favorite kind of story question. We also calculated the overall rating for all the 3 stories and compared it with the rating of Story C. The difference was only about 0.37 out of 5. The difference was not large, which indicated

that Story C would be sufficient enough. Both boys and girls indicated that Story C was their favorite and both had the same order of preference. However, we found that girls gave higher ratings for all the stories, which indicated that girls were more pleased with our story ideas than boys.

4.2 Development Process

Unlike the surveys, our narrative intervention did not go through a series of clearly defined iterations. Instead, it gradually changed over time to reflect new ideas from the team and input we received from our advisers.

Based on the results of our surveys, the four most popular genres were mystery, action, adventure, and fantasy. The story idea involving a lost twin brother garnered the most interest, and because it incorporated two of the most popular genres, adventure and mystery, we decided to develop this story further.

4.2.1 Story

In our story, the player is on a mission to find his or her missing twin brother, using their knowledge of geometry to solve various puzzles to progress through the story. As the intervention is open to both genders, we decided not to define the gender of the main character. Instead, we refer to the player in the second person, describing their actions as something “you” do.

At the start of the story, the player wakes up one Sunday morning and finds his or her twin brother Regan is missing. The player quickly discovers Regan has been captured

by a kidnapper named the “Night Shadow”. According to a note left by the kidnapper, the player must solve problems given by the Night Shadow to gain clues to find his or her brother in different places around town, including the player’s house, a nearby park, a fishing pond, and an old house. At the end of the story, it is revealed that Regan is the Night Shadow. He prepared a surprise birthday party for himself and the player, and used the puzzles to guide the player to the party’s location. We decided on this ending instead of one where the player confronts the Night Shadow to avoid possible criticism of the story.

4.2.2 Intervention Outline

Our program contains eight problems with a hint system for every problem. If the player has difficulty understanding or answering a problem, they can click a hint button. Each press reveals another, more helpful, hint. Because we we were less interested in the student’s ability to correctly answer the problems as we were in their reactions to the narrative, the final hint for each problem states the answer. This way, students would not be stuck on any of the problems, and would have time to complete the post test at the end of the intervention.

In addition to hints, some problems contained “scaffolds”. For these problems, if the student does not provide the right answer, a small set of easier problems appear to help familiarize students with the mathematical concepts of the problem. The last scaffold in the system is always the original question of that problem. If the player still doesn’t get it right, a hint window will appear with the correct answer of the problem.

The first problem starts with an introduction, telling the player that his or her twin

brother Regan was kidnapped by the Night Shadow. In order to find Regan, the player must solve the math problem in a note left by the kidnapper. In this problem, a map of the player's house is provided and the player needs to use the concept of similar shapes to determine which room in his or her house contains the next clue from the Night Shadow. The player is given a rectangle labeled on its length and width, and told to compare it to the floor-plan to find out which rectangular room has the same ratio between dimensions.

After discerning that the next hint is in the dining room, the player must solve another similar shape problem to choose the right place in town to head to next. In this problem, the player is presented a small map of the town with a fishing pond, a middle school, a camp ground, and the player's home prominently marked. Again, the player is given a shape, this time a triangle, and told to compare it to the map to find the triangle with the same ratio between dimensions. This one is harder, however, as the map contains three triangles sharing the same base. This is also used to prepare the player for the next two problems, which both utilize similar triangles. Once the player figures out the fishing pond is the next stop, they leave immediately.

On the way to the fishing pond, the player meets a park ranger named Tom. He asks the player to help measure the height of a nearby swing set, mentioning that he left his measuring tape at home. In a classic shadow problem, the player finds the height of the swing using the Tom's height and the shadow lengths of Tom and the swing set. In return for helping him, Tom shows the player a shortcut to the fish pond.

In order to reach the pond, the player must cross a river. However, there is no

bridge, so Tom suggests the player pushes one of three dead trees near the bank over to form a bridge. Tom cautions the player to only use the tree with the exact right height, for fear of knocking over trees on the other side of the river. The player must once again solve a shadow problem, given the width of the river, the height of the player, and the shadow lengths of the player and the three trees.

Once the player arrives at the fishing pond, he or she meets a fisherman named Old Man Bobbins, who suggests the player check the pond since he thought he saw Regan leave something in it. To do that, the player helps Bobbins make a net by calculating how much rope is needed to encompass the pond (the pond's circumference), and how much magnetic netting is needed to cover the center of the lake (the pond's area). Next to the pond is a 1:20 scale diagram of the pond with exact values of the miniature's radius, circumference, and area. The player uses the information from the miniature pond to find the circumference of the actual pond. In the next problem, the player finds the pond's area in the same manner, and gives both figures to Bobbins. He quickly creates the net and helps the player throw the giant net into the pond, which fishes up Regan's boot and another clue.

According to this new clue, Regan has been taken to an old house on the edge of town. When the player arrives at the house, the front door is locked by a two-digit combination lock. To open the lock, the player must provide the ratio between two similar pentagons to enter the house. Once the player enters the house, another similar mathematical problem appears on a letter hung on the back door. In order to get to the backyard of the house, the player needs to enter the pass code on another combination

lock. This time, the answer is a list of the dimensions of a polygon, calculated from a larger similar shape. After the player enters the backyard successfully, he or she has completed all of the math problems. The player's twin brother was actually the kidnapper who planned the whole process to bring the player to their surprise birthday party.

The biggest challenge the team confronted was how the story appeals the middle school students. In order to achieve this goal, the team changed the wordings of some problems to make it easier to read for the 7th grade students and added some pictures to help them visualize. We also had to remove some of the problems that we initially intended to include after discussing with our advisor to avoid problems that are too difficult to solve for the 7th grade students. The team also changed the format of answers for some problems to multiple choices to ease the difficulty of the mathematical side.

4.2.3 Pre and Post Tests

The pretest contains six geometry math problems with the same concepts to the one in the intervention. Its main function is to verify that the students interacting with the intervention have the basic mathematical knowledge needed to complete each problem. The first three questions contain the concepts of perimeter, area and ratio of the length between two similar triangles. They correspond to the first four problems in the intervention, those that take place in the player's house and the park. The fourth and fifth problems focus on circles, and Students are required to find the circumference and area of a circle. These two problems relate to the fishing pond problems in the narrative intervention. The last problem is about the scale factor between two similar polygons and it corresponds to the

old house problem in the intervention. The team used the test mode in ASSISTments to distribute the pretest. It means the system does not tell the user whether the answer is correct or not; instead, once students enter the number in the answer box, the system automatically jumps to the next problem.

The post-test is for getting feedback on the intervention, and consists of 8 questions. The first question asks the player's gender. The next six questions aim at getting feedback about the assignment. Students are asked how much they enjoyed the assignment and how easy they think the assignment was. Students are asked whether they like the story or not. We also ask for students' feedback on the characters in the intervention and who their favorite character is. The next question asks the students whether the assignment with narrative elements increase the interest of the assignment. The answer choices for most questions in the post-test are provided in the multiple choice mode and their answer choices are provided in different levels to make it convenient for the students to choose. The final question asks for any extra comments the students might have.

V. Future Work and Conclusions

Due to the limited amount of time given, we were only able to finish a rough design of a narrative intervention containing elements of mystery, adventure and action. Most of the problems that we encountered in creating our narrative design lie in the limitations of ASSISTments. In order to stay within the context of ASSISTments, we had to sacrifice some of our narrative ideas that required different versions according to the decisions made by the player along the storylines since ASSISTments only allows a linear progression of problems. This linear storyline puts limitations on creating narrative for the scaffolds since we always have to come back to the original story. This leads to the fact that the students who perform poorly on the math problems are exposed to more of the narrative by getting into scaffolds. Whether this is advantageous to the students would have to be researched further.

Other problems with creating our narrative intervention in ASSISTments were formatting of the problems and scaffolds. The program requires that a problem is answered correctly in order to proceed to the next problem. This has imposed restrictions on having to provide answer for every problem in the form of hints which could potentially lead to difficulty in analyzing data. Although ASSISTments provides the ability to include scaffolds and hints to the problems, the formats of the scaffolds seem confusing due to the limited ability of the web page on ASSISTments.

If we had more time for this project, our biggest next step would be to have our

narrative intervention tested by the 7th graders. In order to do that, we might need to modify some of our scaffolds to improve clarity. The next step would be to create our own web-based system that have capabilities to accommodate different kinds of story lines and scaffolds since we encountered many difficulties with designing our intervention in ASSISTments. The data would then be analyzed to find out the effect of using narrative and the mistakes that need to be avoided. After that, further iterations would be created to improve our design.

One important aspect that we considered in designing our narrative was the ability to scale it up with more educational content in the future. Our background research on the series books revealed that many of the middle school students nowadays enjoy reading series books which leads to the idea of creating serials with recurring characters for our narrative intervention. Therefore, the next step for this narrative intervention after testing it with the students would be to create a similar storyline, possibly a sequel, with more educational content. If our team were to create the same narrative again, we expect it would take about one third of the time that took us to create the 1st iteration since we are already familiar with ASSISTments and we have done background research on the narrative and the behaviors of middle school students.

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Appendix A: Surveys

Iteration 1

Front side of the paper

The following is a questionnaire to help students at WPI design a new program to help students learn. Please answer the questions completely. The more information you provide, the more helpful your responses will be.

Please put a check mark next to your current grade.
Grade: _____6 _____7 _____8

Gender: _____ Boy _____ Girl

1.) What types of reading do you like? (Circle all that apply.)
comics novels fiction nonfiction
magazines newspaper other_____

2. What genre is most exciting to you? (Circle ONE.)
Adventure Mystery Action Non-Fiction Fantasy
other:_____

3. Do you like word problems? Yes No

4. Describe your favorite character from a book, TV show, or movie.

5. How many hours a week do you read for fun? _____

6. Do you read book series? Yes No
If yes, what is your favorite?

7. Do you like shows where the main character has a side kick? Yes No

8. Do you like when the main character is battling one main enemy? Yes No

Back side of the paper

9. Rate the following stories (1 to 5) based on your interest in reading that story.
1= Not interested at all 5= Very Interested

A. The main character is in his early teens and there are rumors in his town that aliens are going to take over the town soon. The main character must prove to the town that these are false rumors by fighting with the bad guy spreading the false news.
Rating: _____

B. The main character is in his early teens and someone close to the main character went missing. He is now on a mission to solve the mystery behind it and find the lost person.
Rating: _____

C. Imagine you are the owner of Six Flags Amusement Park. During the economic recession period, in order to have more customers on your playgrounds to increase the daily earnings, you plan to invent new appealing rides to attract people's attention. Before you reach that goal, you need to study some existing facilities like the Merry-Go-Round, Ferris wheel, Roller coaster, tilt-a-whirl, swinging inverter ship and so on. After getting ideas about how these rides function, it's time to look into the design from engineers you hired to see whether their goal is achievable or not.
Rating: _____

Iteration 2 - Transcribed from ASSISTments

Problem 1

A) Hello! We are college students working on a project about students like you. We are studying ways to make school more fun and interesting, but we need to know more about you. We want to know about your reading habits, and what sorts of things you like in a story, be it in a book, a movie, or a game. Please answer the questions as honestly as you can, since we'll be using your answers to make lessons you might one day be taking!

To begin the survey, What grade are you at in the middle school?

- 6th Grade
- 7th Grade
- 8th Grade

B) 1. Are you a boy ot a girl? (We'd like to know, since girls and boys sometimes like different things.)

- Boy
- Girl

Problem 2

2. Do you like to read the news?

- 0. I never follow the news
- 1. I rarely follow the news
- 2. I sometimes read the front page
- 3. I often read the news

Problem 3

3. Do you like to read magazines?

- 0. I never read magazines
- 1. I only look at the pictures
- 2. I sometimes read magazines
- 3. I often like to read magazines

Problem 4

4. Do you like to read comics?

- 0. I never read comics
- 1. I read comics rarely
- 2. I read comics sometimes

- 3. I read comics often

Problem 5

5. Do you like to read short stories?
    - 0. I never read short stories
    - 1. I rarely read short stories
    - 2. I read short stories sometimes
    - 3. I like to read short stories often

Problem 6

6. Do you like to read novels?
    - 0. I never read novels
    - 1. I read novels, but rarely
    - 2. I read novels sometimes
    - 3. I read novels often

Problem 7

7. Do you prefer fiction or non-fiction?
    - Fiction
    - Non-fiction

Problem 8

8. Do you like word problems?
    - Yes
    - No

Problem 9

9. Describe, in 2 or 3 sentences, your favorite character from a book, TV show, or movie.

Problem 10

10. Do you like when the main character is battling one main enemy?
    - Yes
    - No

Problem 11

11. On average, how many hours a week do you read for fun?

Problem 12

12. Do you read books series? What is one of your favorites?

Problem 13

13. Do you like shows where the main character has a side-kick?

- Yes
- No

Problem 14

A) 14. What is your favorite kind of story?

- Adventure
- Fantasy
- Mystery
- Action
- Realistic Fiction
- I don't have one
- Other

B) If you chose "Other" for question 14, write your answer here.

Problem 15

A) Rate the following 3 stories on a 1 to 5 scale with 1 being the least interesting.

A. You're a famous detective living in the big city. One day, a man walks into your office with a new case - he's lost his magic wand and he needs you to find it. Although he sounds crazy, you decide to take the case. As you search, you'll discover that magic isn't just for fairy tales and things are not always as they seem.

- 1. I don't like it
- 2. I sort of like it
- 3. I like it
- 4. I like it a lot
- 5. I love it!

B) B. The kids in your town have always been warned to stay away from a local cave, as parents believe it to be haunted. You and your friends don't believe them, and go anyways, only to find the stories are true! However, the ghosts are friendly and asked for your help to break the curse forcing them to haunt the cave. You need to help them in order to make your way back home.

- 1. I don't like it
- 2. I sort of like it
- 3. I like it

- 4. I like it a lot
- 5. I love it!

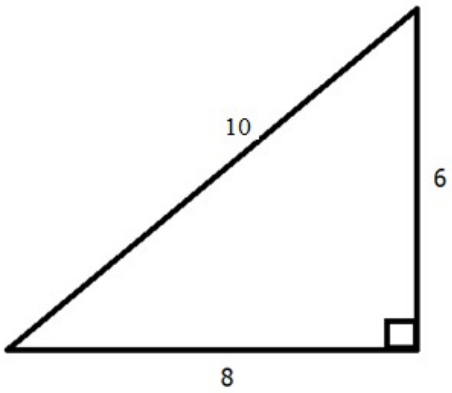
C) C. You're a young teen living in a small town and your twin brother has suddenly gone missing just a day before your joint birthday. You're now on a mission to solve the mystery behind his disappearance. You need to collect clues and talk to people around town to find him before the party. Time is short and your brother is counting on you!

- 1. I don't like it
- 2. I sort of like it
- 3. I like it
- 4. I like it a lot
- 5. I love it!

Appendix B: Pretest and Post-test

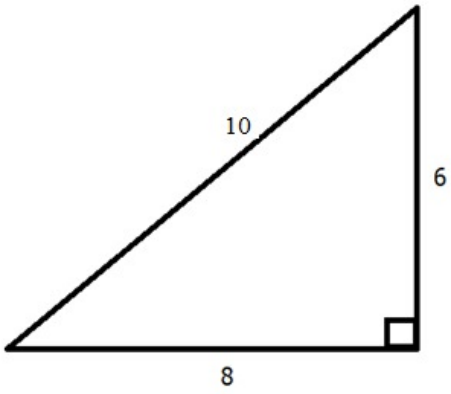
Pretest - Transcribed from ASSISTments

Problem 1
A) You are about to enter a mystery. Before you start, you will need to answer the next 6 question. Let's get started!
1. Find the perimeter of the triangle.



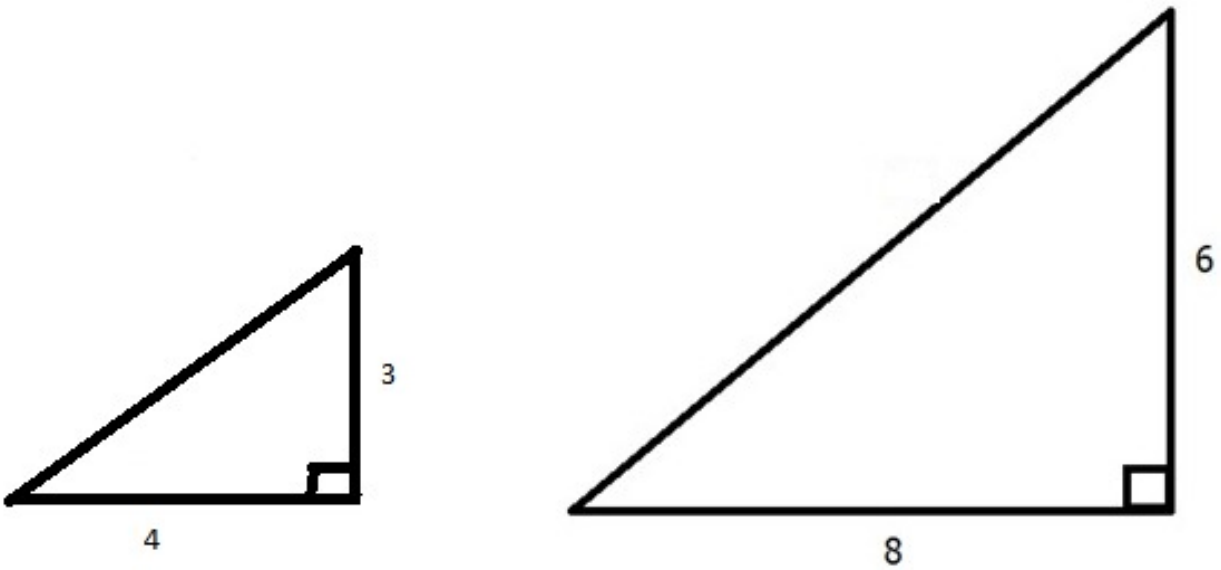
Free Response Answer

B) 2. Find the area of the triangle.



Free Response Answer

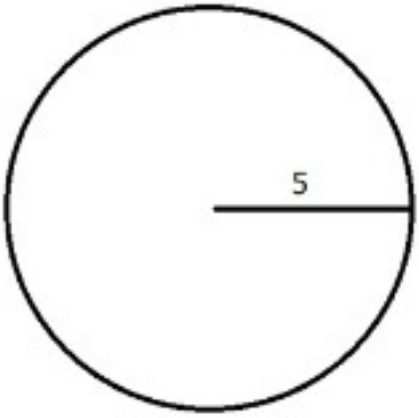
C) 3. Below are two similar triangles, please find the ratio of the length of the bigger one to the smaller one. Three more problems until you can start the mystery!



Free Response Answer

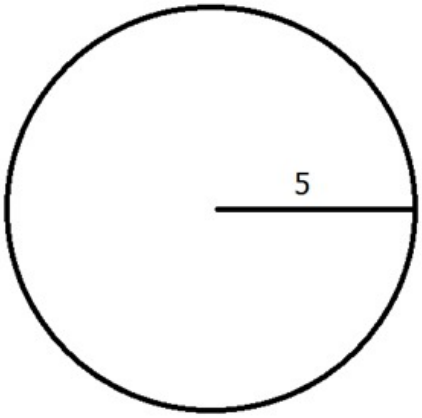
Problem 2

A) 4. Find the perimeter of this circle. Use 3.14 for pi.



Free Response Answer

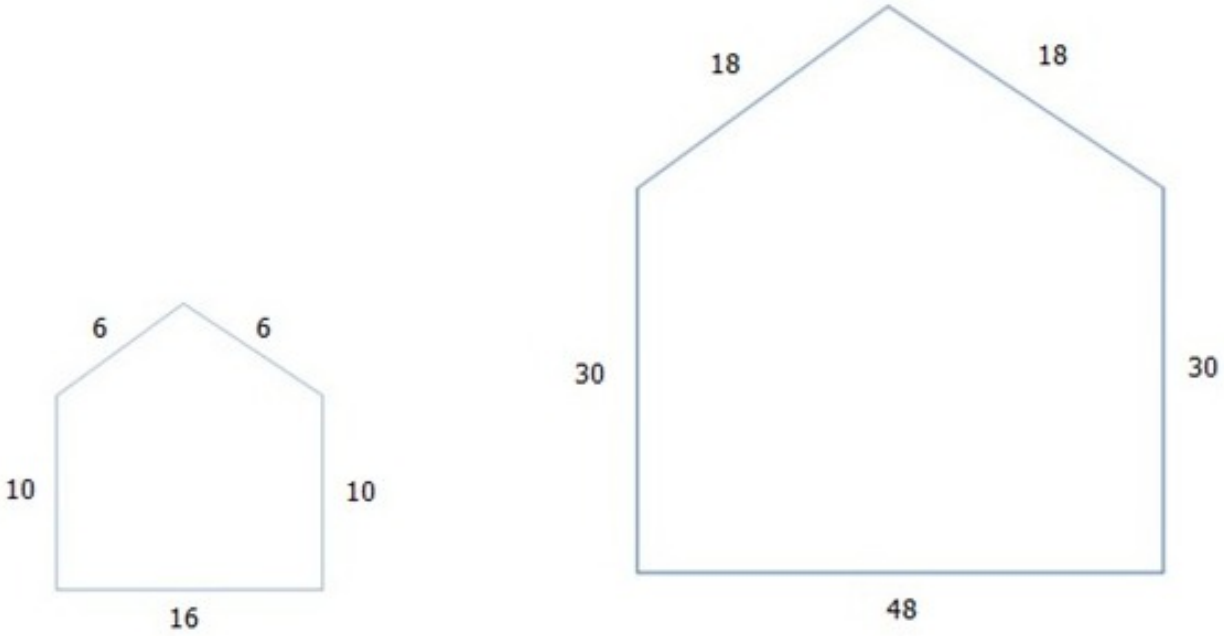
B) 5. Find the area of the circle. Use 3.14 for Pi.



Free Response Answer

Problem 3

A) 6. What is the scale factor between the two similar shapes provided?



Free Response Answer

B) You have succesfully finished the math review section. Let's now move on to the interesting story!! Get Ready for the adventure!!

- Click here to start the adventure

Post-test - Transcribed from ASSISTments

Problem 1

1. How much did you enjoy this assignment?
   - Not at all
   - A little bit
   - Somewhat
   - A lot
   - I love it!

Problem 2

2. Overall, how easy was the assignment?
   - Too hard – I couldn't figure out any of the answers
   - Tough – I had a hard time figuring out most of the answers
   - Just right – I knew some answers, and could figure out the rest
   - Not bad – I knew most of the answers and figured out the rest
   - Easy – I knew all of the answers without any help

Problem 3
3. Were the stories too long?
- Yes, there was too much reading
- It was just right
- No, I wish it were longer

Problem 4
4. Were the stories enjoyable?
- Yes, they were fun to read
- They were okay
- I hated them

Problem 5
5. Did you like the characters in the assignment's story?
- No, they were boring or annoying
- They were alright
- Yes, they were interesting and enjoyable

Problem 6
6. Who was your favorite character from the assignment?
- Regan: Your twin brother
- Tom: Park Ranger from Shadow problem
- Old Man Bobbins: The owner of the fish pond

Problem 7
7. Would you find learning the material in the assignment more interesting if it was taught in a regular way?
- Yes, I would like it more if my teacher taught it to me
- I don't think it would be any different
- No, this is definitely more interesting than a regular assignment

Problem 8
Please write any other comments you have in the box below.
Free Response Answer

Appendix C: Narrative Intervention

Transcribed from ASSISTments

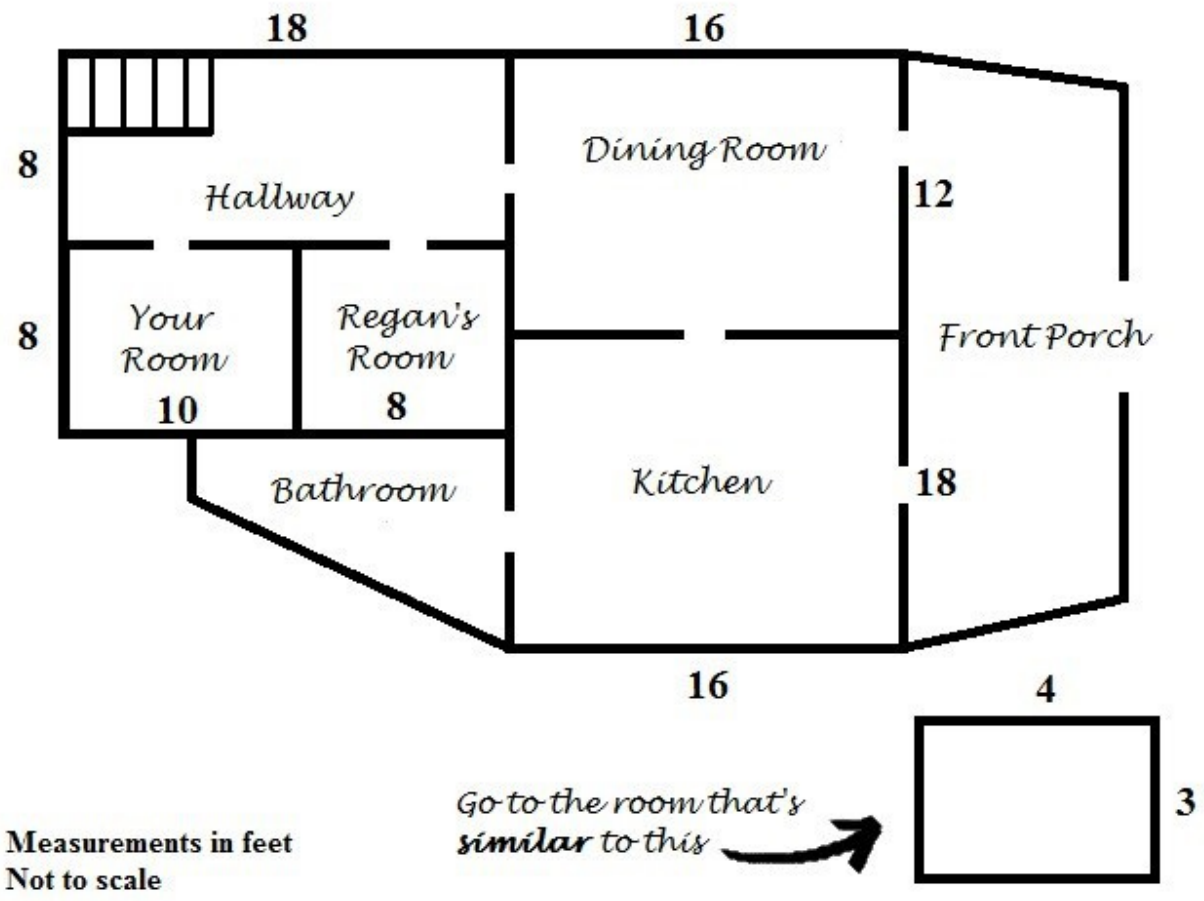
Problem 1

You wake up to the sound of your buzzing alarm clock. You reach over and shut it off before sitting up slowly, thinking about how deep you were sleeping and wishing you didn't have to get up so early. Today is Sunday, so you and your brother are supposed to do morning chores. You grumpily walk to your brother's room and loudly knock. "Regan, wake up already," you demand. After waiting for a minute with no reply, you open his door, only to notice a made bed with no Regan in it. Your parents are not home, and you begin to freak out. You go downstairs, calling for your brother, when you notice a paper on the dining room table.

"Good morning,
I am the notorious kidnapper known only as the Night Shadow, and I have napped kids from around the world. Now I have taken your brother, likely never to be seen again! I'm feeling generous, though, and have decided to give you a chance to rescue him. Solve my puzzles, and you may yet see your brother once more. Don't even THINK about cheating and letting someone else solved them! I'll know, and you'll never see him again! Are you clever enough to unravel my mysteries?"

On the back side of the letter is a hand-drawn map. After studying it for a minute, you recognize it as a map of your house!

You see that the word "similar" is highlighted, and remember learning about similar shapes in school. Which room is similar to the rectangle at the bottom of the map?



Hints:

1. "Similar" means same proportion. Is there a room whose dimensions are a multiple of 4x3?
2. Look for a room that is 4 times bigger on each side.
3. Multiply each side by four. Is there a room that is 16 feet by 12 feet?
4. The answer is the dining room.

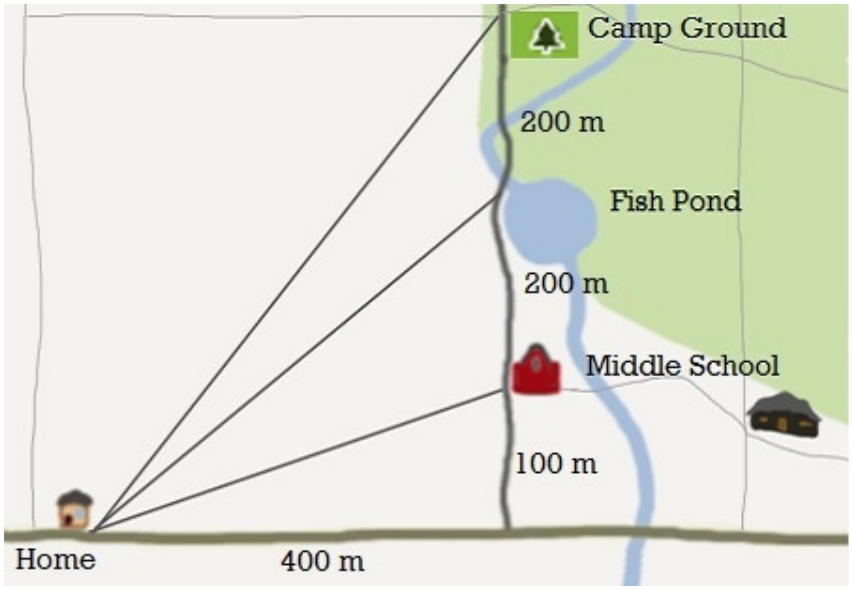
Select one:

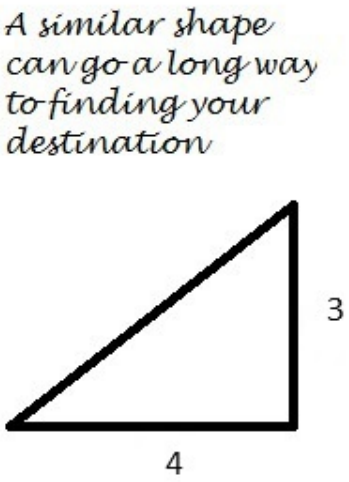
- Hallway
- Your Room
- Regan's Room
- Dining Room
- Kitchen

Problem 2

You scratch your head in confusion. That can't be right! You're already in the dining room. You hunt around the room for another clue, eventually crawling under the table, where you find a second piece of paper taped to the bottom.

The paper shows a map of your town, but it has strange lines drawn on it. To the right of the map is a hand-drawn triangle with two of its sides labeled. A note written above the triangle reads "*A similar shape can go a long way to finding your destination*". You realize that the lines lead to landmarks around town – one to the middle school, another to the fish pond, and a third to a popular camp ground.





Using the clues left by the Night Shadow, where should you go next?

Hints:

1. Notice that the map forms three triangles similar in shape to the triangle on the right. The base of the triangle in the map is 400m.
2. The base of the triangle is 400m. How much do you have to multiply the base of the triangle on the right by to get that answer?
3. Multiply the height of the model by 100 to find the place you're looking for.
4. Remember to add the distances along the vertical road!
5. You should go to the fish pond.

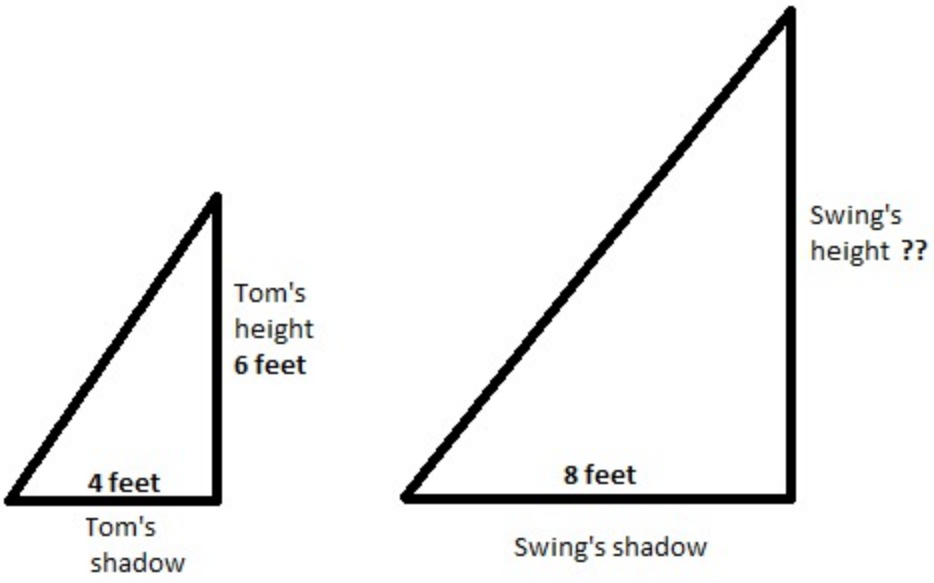
Select one:

- Camp Ground
- Fish Pond
- Middle School

Problem 3

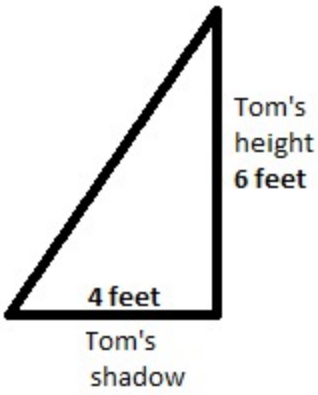
You figure out that the Night Shadow wants you to go to the fishing pond, so you leave right away.
On the way there, you meet a park ranger named Tom. "Hey kid," he calls to you. "Think you could help me out here?"

“I’m sort of in a rush,” you say.
“Great, this will only take a second! I’m supposed to replace the lumber on that swing set over there, but I need to find the height of it first. The only problem is I left my measuring tape at home!” He points over to the swing set. You notice it is standing in a sunny clearing, which gives you an idea.
“My math teacher taught me a trick for measuring tall things like this,” you explain to Tom. “First we have to measure its shadow somehow.”
“I know how!” says Tom. “My boot's length is about 1 foot. We can count how many steps it takes for me to walk the whole shadow!” You both walk to the swing set, and Tom paces the shadow, toe to heel. He takes 8 steps before he reaches the end.
“An 8 foot shadow,” you say. “Now we need your shadow length. Let me take your shoes and measure it out.”
“Couldn’t we just measure your shadow?” Tom grumbles as he takes his shoes off. “My socks will get covered in dirt!” Despite his protest, you measure his shadow to 4 steps, or 4 feet.
“Finally, I need your height. Then we can find the height of the swing set!” you say as Tom pulls his shoes back on.
“I’m 6 feet to the hair.” Tom stands back up. “No more, no less.”
If Tom is 6 feet tall, and his shadow is 4 feet long, how tall is the swing set (in feet) if its shadow is 8 feet long?



Hints:

1. What is the ratio of Tom's height and his shadow?



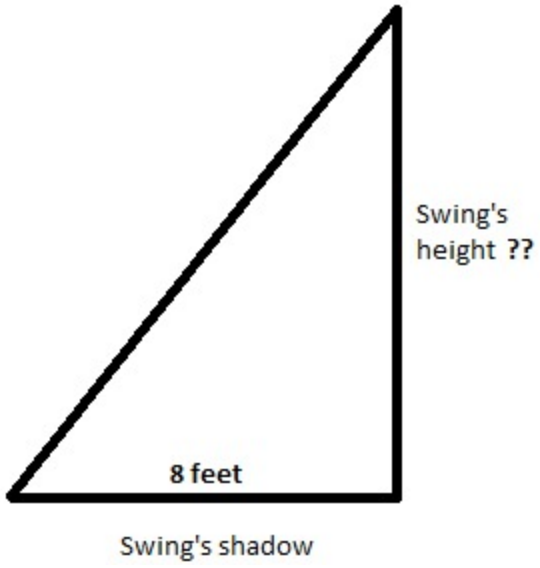
   (Answer: the ratio is 6/4 = 1.5)
2. Which one is taller? The shadow or the height?

   (Answer: the height)
3. The ratio of the length for the swing set to its shadow is also 6/4.
4. If you know that the shadow of the swing set is 8 feet, and you want the length of the swing set, apply the following formula.

$$\frac{length}{8\ feet} = \frac{6}{4}$$

$$\frac{length}{shadow} = \frac{6}{4}$$

$$length = (8\ feet) \times \frac{6}{4}$$



5. The answer is 12.

Free Response Answer

Problem 4

"Perfect!" says Tom. "Thanks for your help!"
"You're welcome," you reply. "But I really need to get to the fish pond now."
"The fish pond?" Tom asks. "I know a short cut there! I'll show you, as thanks for helping me."
You follow Tom along a trail through the woods that you'd never seen before. Tom assures you that it leads right to the fish pond, but you're not so sure. Eventually, you stumble out of the woods on to the bank of a river.
"Well that wasn't here the last time I took that trail." Tom scratches his head.
"You're not a very good park ranger, are you?" you ask him.
"I know this park better than anyone!" he replies. "I just get turned around very easily. But I know for sure that this river runs by the fish pond, and you'll want to be on the other side to get there the fastest."
You spot 3 dead trees near the bank. "If we push one of those trees, we can make a bridge!" you shout. "You said you know this park well, right? How wide is this river?"
Tom thinks for a moment. "It's a little less than 15 feet across this far downriver," he says. "We should try and find a tree that's just the right length for the river. I'd hate to use a tree that's too long and knock over the trees on the other side."
"We can use the same trick we used for the swing set for these trees," you say. "You can even measure my shadow this time."
Standing next to the trees, your shadow is 3 feet long, and you know that your height is 5 feet. If you want a tree that is 15 feet long, how long should the shadow of the tree be (in feet)?

Free Response Answer

Scaffolds:

1) You look around and discover a stick standing next to a tree. It is nearly perpendicular to the ground. You estimate the height of the stick is 1 foot and its shadow is 0.6 feet long.
What is the ratio of the height of the stick to its shadow?

Hints:

1. The answer is 5/3.

Select one:

- 5/3
- 3/5
- 4/5
- 5/4

2) You then estimate that the tree the stick stands next to is about 3 feet tall. What is the length of the tree's shadow?

Hints:

1. The answer is 1.8.

Free Response Answer

3) Congratulations for doing so well! Let's try to cross the river again. Standing next to the trees, your shadow is 3 feet long, and you know that your height is 5 feet. If you want a tree that is 15 feet long, how long should the shadow of the tree be?

Hints:

1. The answer is 9.

Free Response Answer

Problem 5

After you figured out which tree to use as a bridge to cross the river, you successfully cut down the tree with the help of Tom and got to the other side of the river.

Great job! Now, you arrive at the fishing pond. Your brother is nowhere in sight, but a fisherman, named Old-Man Bobbins, is floating in a boat in the pond.

"Hey, Mr. Bobbins!" you call out to him. "Did you happen to see my brother pass through here?"

"Nope," he says, "but if he did, it's possible he left something in the pond, eyup. What happened to him anyways?"

"Oh, nothing," you lie. "I just thought he might be here. Maybe you fished something of his from the pond?"

"Well, to do that, I'd need a bigger net. But to make one, I'd have to unroll a rope around the whole dang perimeter of the pond. Then I'd have to figure out how much netting I'd need to fill the whole area. But I don't know how to do somethin' like that! I only made it to the sixth grade."

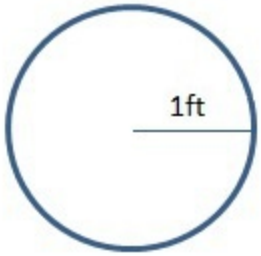
You think for a minute. "I have an idea how. How wide is the pond?"

"I don't know exactly," he replies, "but there is the miniature pond. I guess you can use it to figure out the width of the actual pond."

He points to a small billboard next to you. On it is pinned a picture of the miniature pond. A

label reads, “This picture is scaled 20 times smaller than the fishing pond”.

The following is the miniature pond with its dimensions. Its radius is 1 ft, the circumference is 6.28 ft, and the area is 3.14 square feet.



You remember using the scaling factors for similar shapes in your math class. "Alright," you say, "I guess I know how to figure it out. It’s time to use my geometry skills in real life!"

What is the circumference of the pond? Remember that the formula for finding the circumference of a circle is 2*pi*r. Use 3.14 for pi.

Free Response Answer

Scaffolds:

1) Let's say there are two circles, a big one and a little one. The radius of the big circle, *B*, is two times the radius of the smaller circle, *L*. (*B* = 2*L*)

What is the circumference of the big circle in terms of *B*? Only give symbolic form. Use 'pi' for 'π'.

Hints:

1. Replace the radius in the circumference formula with the radius of the big circle.
2. The answer is 2*pi*B.

Select one:

- pi*B
- 2*pi*B
- 4*pi*B
- 8*pi*B

2) What is the circumference of the small circle in terms of L? Only give symbolic form. Use ‘pi’ for ‘π'.

Hints:

1. Replace the radius in the circumference formula with the radius of the small circle.

2. The answer is 2*pi*L.

Select one:

- pi*L
- 2*pi*L
- 4*pi*L
- 8*pi*L

3) Now compare the circumference of the big circle and the circumference of the small circle based on the answers from the previous problems. How many times bigger is the circumference of the big circle than the circumference of the small circle?
Remember that the circumference of the big circle is 2*pi*B, the circumference of the little circle is 2*pi*L, and B=2L.

Hints:

1. Compare 2*pi*L to 2*pi*B. The only difference in the circumferences is the radius.
2. How many times bigger is B than L?
3. The answer is 2.

Select one:

- 2
- 4
- 6
- 8

4) If the circumference of the small circle is 5, what is the circumference of the big circle?

Hints:

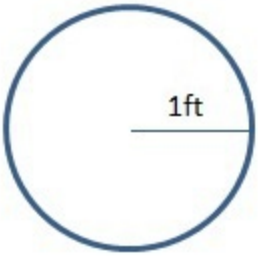
1. The answer is 10.

Free Response Answer

5) Now let's try the original problem again.

He points to a small billboard next to you. On it is pinned a picture of the miniature pond. A label reads, "This picture is scalled 20 times smaller than the fishing pond."

The following is the miniature pond with its dimensions. Its radius is 1 foot, its circumference is 6.28 feet, and its area is 3.14 square feet.



You remember using the scaling factors for similar shapes in your math class. "Alright," you say, "I guess I know how to figure it out. It's time to use my geometry skills in real life!"

What is the circumference of the pond? Remember that the formula for finding the circumference of a circle is 2*pi*r. Use 3.14 for pi.

Hints:

1. How much bigger is the actual pond's radius than the miniature pond's radius?
2. Because the pond's radius is 20 times larger than the picture's radius, the pond's circumference is also 20 times larger than the picture's circumference. Multiply the miniature pond's circumference by 20.
3. The answer is 125.6.

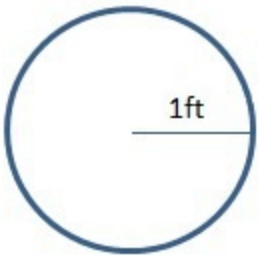
Free Response Answer

Problem 6

"How about the area?" Mr. Bobbins asks. "I need to know the area to figure out how much netting I need for my magnetic fishing net."

You are fascinated by the sound of magnetic fishing net. "Yes, definitely," you reply. "Since I already know the area of the miniature pond, I can find the area of the actual pond by figuring out how many times the area is scaled."

The following is the miniature pond with its dimensions. Its radius is 1 ft, the circumference is 6.28 ft, and the area is 3.14 square feet. The pond is 20 times bigger than this picture.



What is the area of the pond? The formula of the area of a circle is A = pi*r^2. Use 3.14 for pi.

Free Response Answer

Scaffolds:

1) Let's say there are two circles, a big one and a little one. The radius of the big circle, B, is two times the radius of the little circle, L. (B = 2L)

What is the area of the big circle in terms of B? Only give symbolic form. Use 'pi' for 'π'.

Hints:

1. Replace the radius in the area formula with the radius of the big circle.
2. The answer is pi*B*B.

Select one:

- pi*B*B
- 2*pi*B
- 2*pi*B*B
- 4*pi*B*B

2) What is the area of the small circle in terms of L? Only give symbolic form. Use 'pi' for 'π'.

Hints:

1. Replace the radius in the area formula with the radius of the small circle.
2. The answer is pi*L*L.

Select one:

- pi*L*L
- 2*pi*L
- 2*pi*L*L
- 4*pi*L*L

3) What is the area of the large circle in terms of *L*? Remember that *B* = 2*L*.
Only give symbolic form. Use 'pi' for 'π'.

Hints:

1. Remember the area of the big circle in terms of B. How many L would fit in that formula?
2. The answer is 4*pi*L*L.

Select one:

- 2*pi*L*L

- 4*pi*L
- 4*pi*L*L
- 8*pi*L*L

4) Now compare the area of the big circle and the area of the small circle, based on the answers to the last few problems. How many times bigger is the area of the big circle than the area of the small circle?

Hints:

1. The answer is 4.

Select one:

- 2
- 4
- 6
- 8

5) If the area of the small circle is 10, what is the area of the big circle?

Hints:

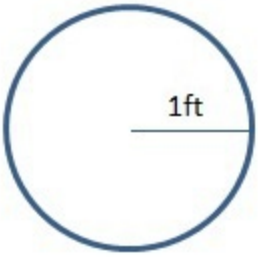
1. The answer is 40.

Free Response Answer

6) Congratuations for doing so well! Now let's try the original problem again.

“Yes, definitely,” you reply. “Since I already know the area of the miniature pond, I can find the area of the actual pond by figuring out how many times the area is scaled.”

The following is the miniature pond with its dimensions. Its radius is 1 ft, the circumference is 6.28 ft, and the area is 3.14 square feet. The pond is 20 times bigger than this picture.



What is the area of the pond? The formula of the area of a circle is $A = pi*r^2$. Use 3.14 for pi.

Hints:

1. What i the area of the pond in terms of the picture's radius? How many times larger than the picture's area foes that make the pond's area?
2. The answer is 1256.

Free Response Answer

Problem 7

"The area is 1256 square feet," you explain.

"Ah, that's all I need to know," says Old-Man Bobbins. If ya gimme a minute kid, I'll get this net wound up and made in a jiffy!"

In just five minutes, Old-Man Bobbins spins up a net the size of the fishing pond.

"Wow, that was quick," you say.

"Old family secret! Now let's see if there's anything hidden in that pond." Old-Man Bobbins throws the giant net into the pond and pulls up a boot belonging to your brother. You look inside the boot and find a note.
"78 Park Street," it reads. You quickly realize it is the handwriting of your brother.

Mr. Bobbins points out that is the address of the deserted old house to the south of town. You dash to the old house as quickly as you can without even saying goodbye to Mr. Bobbins.

Select one:

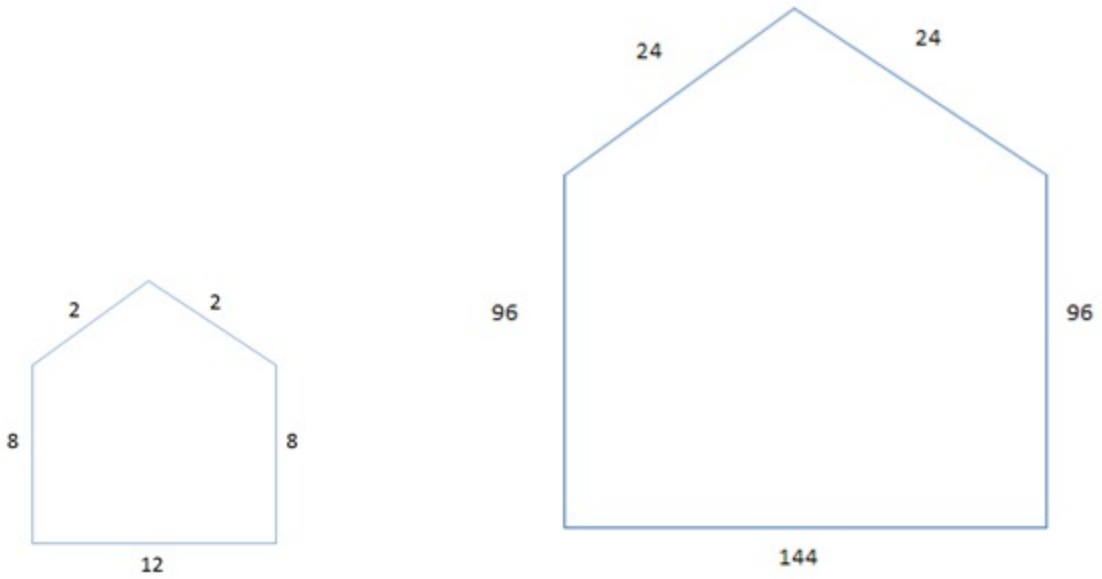
- Move to the old house

Problem 8

You finally arrive at the old house, but as you try to get in, you realize that you need a password to enter the house. There is a combination lock on the front door, and all the windows are heavily boarded. It stops you for a minute and you think to yourself, "This password needs to be a combination of numbers, and it must somehow be related to some kind of math problem, since I've been solving math problems all the way".
As you are thinking to yourself, you spot an old piece of paper poking out from under the door. You immediately unroll the letter. The paper reads:

"*Congratulations! You made it here, but I have something more for you. The pentagon shown in the following is the shape of this house. The first one is the smaller model of the house, and the second one gives the actual dimensions of the house. You have to figure out their relation!*"

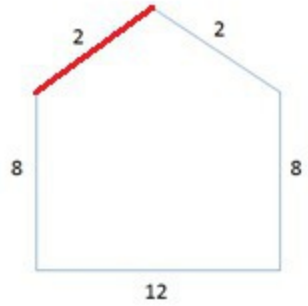
After you read the letter, you figure out that since the two pictures are the same shape, and the smaller one is a small scale of the larger one. The two pictures are related by a scale factor.

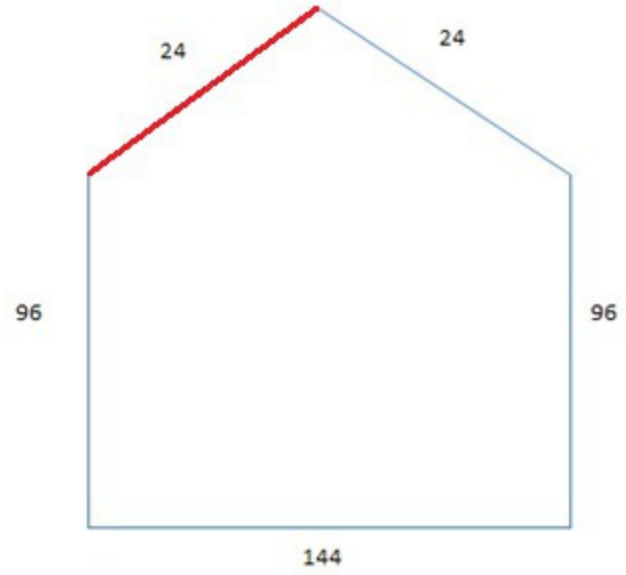


Now find out what the password should be. The password is a 2 digit number.

Hints:

1. The figure on the right is larger than the figure on the left by how many times?
2. How many times bigger is the colored side in the large figure than the colored side in the small figure?





3. The answer is 12.

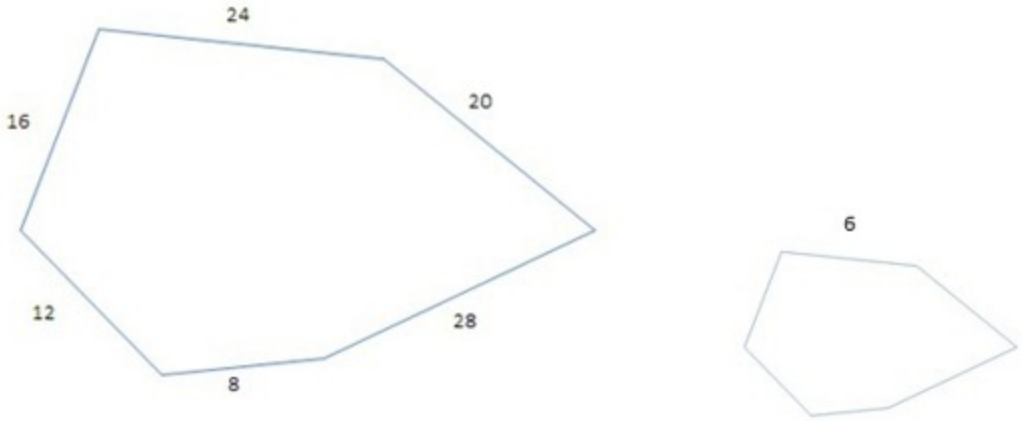
Free Response Answer

Problem 9

Now you successfully enter into the old house. You are expecting to see your brother, but you only hear some music in the air that seems to be coming from the back of the house. You decide to follow the music and find out what it is. But unfortunately, you need to pass through another door to get there, and there is a password again.

However, this time, you find a letter hung on the door. The letter has 2 pictures in it. It says “This is the shape of the backyard you’re about to enter. The picture on the left is the shape of the yard with actual dimensions, and the one on the right is a smaller scale of the yard. If you want to know the password, figure out all the corresponding lengths.”

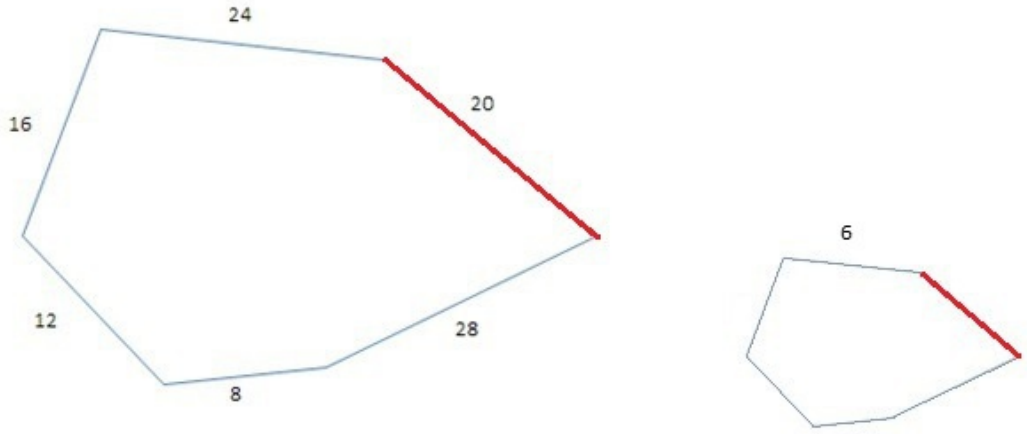
What's the 6 number password? In the clockwise order of the figure, your first number is 6. An example to write your answers is 3,5,7,8,9,2.



Free Response Answer

Scaffolds:

1) The scale factor of the large figure to the small figure is 24/6 or 4. What is the length of the colored side in the small figure if the corresponding colored side in the large figure has the length of 20?

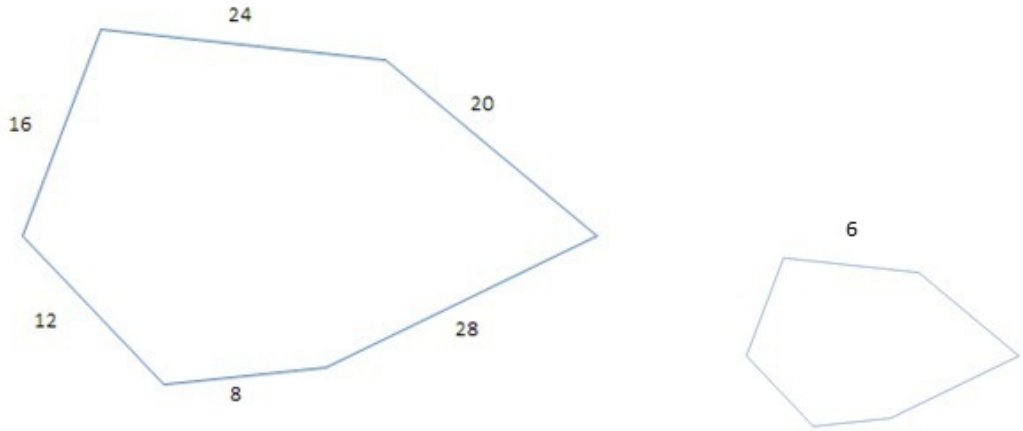


Hints:

1. The answer is 5.

Free Response Answer

2) Let's try the original problem again. The picture on the left is the shape of the yard with actual dimensions, and the one on the right is a smaller scale of the yard. If you want to know the password, figure out all the corresponding lengths.



What's the 6 number password? In the clockwise order of the figure, your first number is 6. An example to write your answers is 3,5,7,8,9,2.

Hints:

1. The answer is 6,5,7,2,3,4

Free Response Answer