IMPROVING FEEDBACK IN ASSISTMENTS

Pedagogical Agents and Game-Like Elements

Interactive Qualifying Project Report completed in partial fulfillment

of the Bachelor of Science degree at

Worcester Polytechnic Institute, Worcester, MA

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1 Introduction

Keeping students motivated is a central concern in the field of education. Video games have provided us with a wealth of information on how to keep people engaged with a piece of software. Modern technology has allowed us to deploy computerized tutoring systems such as ASSISTments. While such a system makes education more efficient, student motivation still has room for improvement. Since ASSISTments bestows classrooms with other benefits of computation, shouldn't it borrow techniques from video games to enhance student engagement? We argue that it should. But first, it is important to understand what ASSISTments is and what problems it tries to solve.

Assessing student performance is an important facet of education. Test scores are an indicator of where to focus teaching efforts, which departments need more funding, who is falling behind, and other similar properties. This information is necessary for effective teaching and administration. However, gathering this information often conflicts with the central goal of education: to provide knowledge. Every test a teacher has to perform and spend time grading means another lost lecture or activity. There must be a better way:

> "One can imagine a future in which the audit function of external assessments would be significantly reduced or even unnecessary because the information needed to assess students at the levels of description appropriate for various external assessment purposes could be derived from the data streams generated by students in and out of their classrooms." (Assessment, Pellegrino and Chudowsky 284)

ASSISTments addresses this problem by combining assessment tools with the learning process via an online platform. Teachers can assign questions to students, who answer them on the ASSISTments website. Since the service provides assistance to the student by breaking down problems and giving feedback, it helps them learn the material better than solving traditional homework problems out of a book or worksheet. Automatic grading and reporting tools make life easier for teachers, as well.

The ASSISTments platform has a long history with the WPI community since its inception in 2003 (Heffernan). WPI Professor Neil Heffernan serves as Project Director for ASSISTments. Many WPI students and other faculty members have contributed to the project. The project has received millions of dollars in funding and is used by thousands of students.

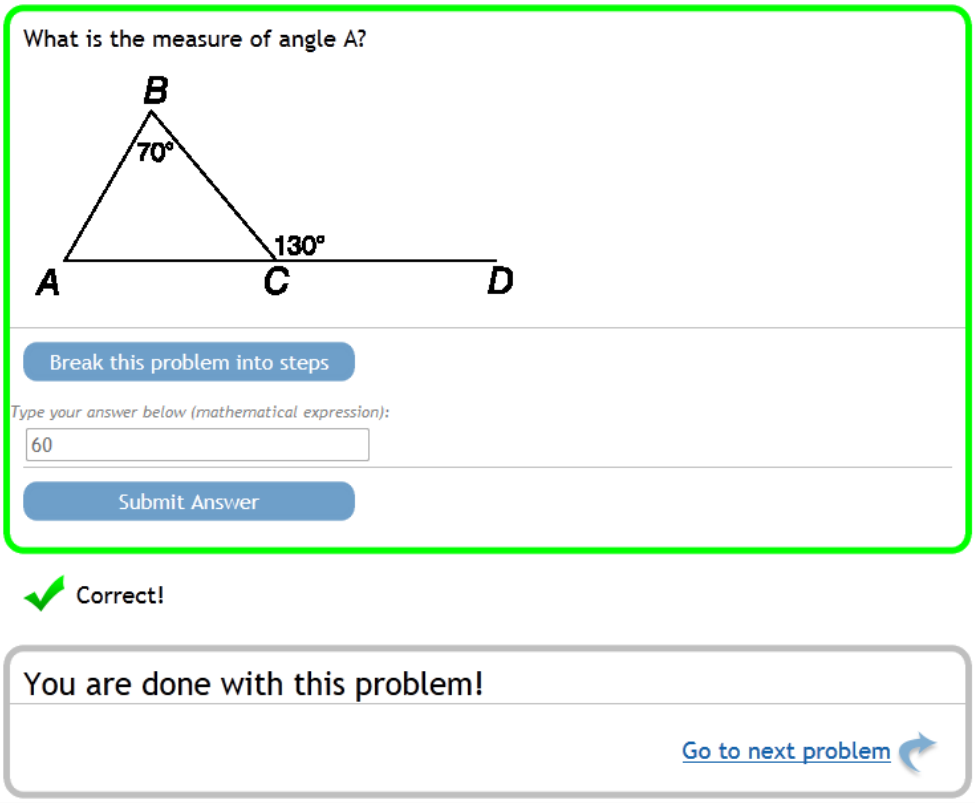


Figure 1 – A correctly answered problem in ASSISTments

ASSISTments works well enough for teachers, but the experience can be greatly improved for students. Ideally, students would find the system to be highly enjoyable and be motivated to complete more problem sets. Gee asserts that "Motivation is the most important factor that drives learning. When motivation dies, learning dies..." (3). ASSISTments is passing up many opportunities for improving motivation and learning that other educational systems take advantage of.

Video games are an excellent example of such an educational system. Nearly all modern games must teach players how to play the game, be it through an explicit tutorial,

constant feedback during gameplay, instruction manuals, other players, or some combination thereof. Some games are also designed to teach specific skills or facts. Video games use countless techniques to keep the player engaged and motivated. We have examined some of these elements to see what can be borrowed in order to improve ASSISTments.

1.1 Choosing an Element to Study

As a first step, we thought of some game-like elements that could be introduced to ASSISTments which were reasonable ways to achieve our goals of increased motivation, enjoyment, and learning. In order to decide on one element to focus on, we compared elements based on criteria of practicality, since their effectiveness is what we would be researching and determining in the future.

One of our top concerns was how difficult the element would be for teachers to use. Klopfer et al. suggest that logistics and teacher support problems are significant barriers to the adoption of educational software (18). If an element would require a significant amount of extra effort on the part of the teacher, then it's probably not practical to include it in ASSISTments. Making teachers work harder is not consistent with the goals of the system.

Another issue is the ease of implementation from a technical standpoint. Would it be computationally feasible to add such an element? Do we have enough information to

make necessary decisions? There are also pragmatic concerns like the amount of previous research in the field, ease of testing and design, etc.

1.1.1 Narrative

The first element we considered was the narrative present in games. We thought that if we added a complex story similar to one found in a modern video game, students would be more compelled to use ASSISTments. Advancing the story requires students to complete problem sets. If we want students to really care about the story, it needs to be continuous between problem sets and be a quality narrative in and of itself. Quick two minute stories like those present in traditional word problems are not enough to capture their interest. We also considered the possibility of changing the story based on how students answered the questions.

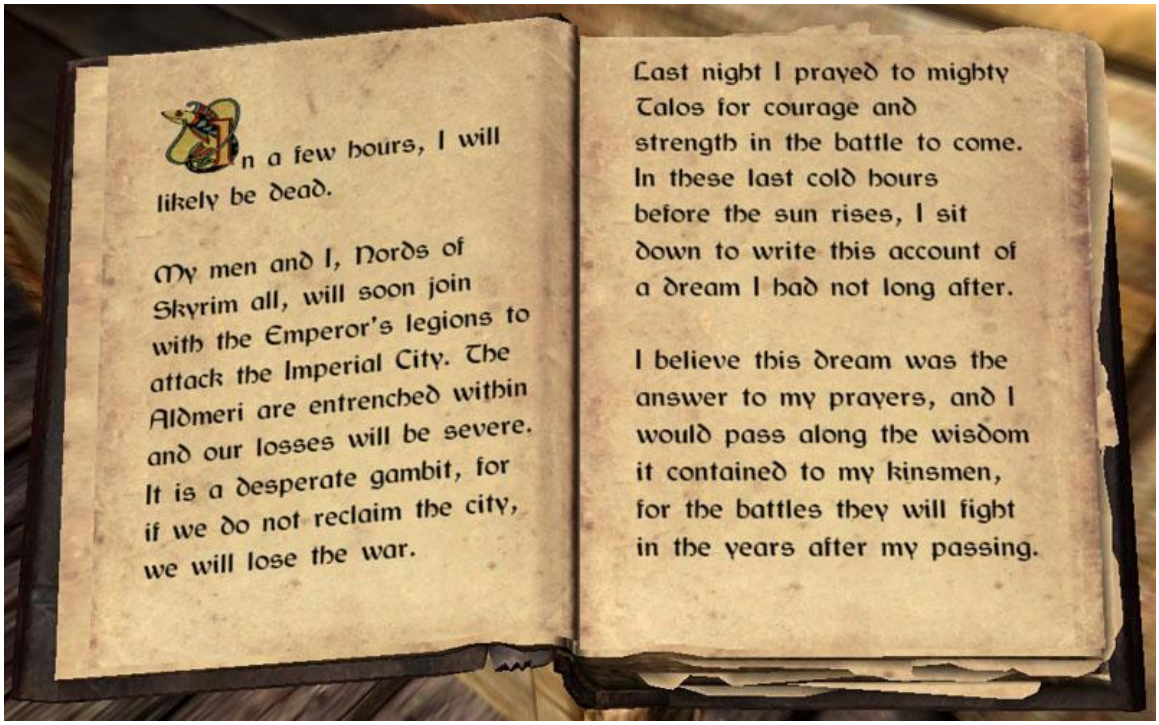


Figure 2 – *The Elder Scrolls V: Skyrim* contains hundreds of books, creating a believable narrative

This element has a few things in its favor. For one, this is extremely easy to do from a technical standpoint – all you need is to allow the teacher to place arbitrary text and pictures in problem sets, which is already possible. Writing up a story should be a familiar task for a teacher. The interface is familiar, since a teacher only needs a text editor to write a story. There's also a possibility of reusing stories between problems to reduce the teachers' workloads. There has been some research in this area, so we will have something to build upon.

However, this element has a number of significant drawbacks. Most obviously, this element requires an inordinate amount of work from teachers. Writing a complex,

compelling, high-quality story to string together all work done on the system is a very difficult task. Some teachers may not be able to write good stories at all, or they may be unable to create convincing illustrations. One might suggest that future IQP groups could work to create reusable stories, but we think this will lead to an undesirable disconnect between the problems and the stories; the two components should be developed to complement each other, and this is difficult to do with boilerplate narratives. Reading the story means additional work for students as well, so they may skip over it anyway.

1.1.2 Variable Difficulty

Another element we considered is that of variable difficulty. This idea is common in games – simpler games might have Easy, Normal, and Hard modes that the player can choose from, and more advanced games might change enemy AI, give the player an extra life after doing poorly, or suggest repeating tutorials. To translate this into ASSISTments, we thought the system should recognize especially poor or good performance. If the student is doing poorly, ASSISTments might review earlier material or give them easier problems. If the student is doing well, it could provide more challenging questions or move on to advanced material. Letting students choose a difficulty level is a bad idea, since apathetic or overconfident students could easily choose a difficulty level that doesn't fit them.

This element does have the advantage of being easier on teachers than the narrative element. The teacher might only have to write a few extra review or advanced problems, rather than come up with a complex narrative. We had also found some previous research

on this subject. However, there are a few disadvantages. From a programming perspective, such a feature would be very difficult to implement. It would have to have a very good idea of what the student knows and identify when review material should be presented – a difficult task. The feature would also be very domain-specific. It would have to be tailored for specific types of problems and gaps in learning, which would make it very difficult to test this element as a general solution to the problem of motivating students.

1.1.3 Feedback

The final element we considered was that of feedback. By feedback, we generally meant immediate reaction from the system that will help or motivate the student. This element is integral to video games. Receiving points, earning spoken praise like “Good job”, and an avatar flashing when taking damage are all good examples of what we were evaluating for inclusion in ASSISTments.

Figure 3 – The *Call of Duty* series is well-known for its feedback mechanisms. The player earns many points for killing enemies, and the screen is splattered with blood when the player takes damage. (PCFormat)

We settled on providing some form of textual feedback after answering a problem. The feedback would change based on the student's estimated knowledge and the difficulty of the problem. For example, if the student did poorly on a question ASSISTments thought he had high knowledge on, it may say, "Come on, you can do better than that." On the other hand, if the student does unexpectedly well, the system would say "Wow, great job! That was a tough one!" We also wanted to let the student earn points and achievements – little trophies or badges for exemplary performance, such as answering 5 problems correctly in a row. This feedback should motivate students to work harder.

This element was very appealing because it requires no extra effort on the part of the teacher. All added features are taken care of automatically. We also knew that a lot of

research had been done in this field, and ASSISTments does keep a measure of student knowledge and problem difficulty. It would be feasible to implement. For these reasons, along with the drawbacks of the other two elements, we chose to study feedback for the rest of the project.

1.2 Project Outline

The idea of "feedback" is very broad and is the concern of psychology, teaching manuals, human-computer interaction, management, and game design. Consequently, we will try to consider literature from many different fields when justifying design decisions.

To formulate our final design, we went through a process similar to iterative design. We reviewed literature on the subjects we were interested in incorporating in our design, made changes we thought were necessary, and presented our design to our advisor and other IQP groups working on similar projects. Based on their feedback and our continued research, we made more changes and repeated the process. One of the stages of the design was shown to a focus group, whose feedback was used in the final design. The rest of this report is structured around each step of our design process.

2 Design 0

After our brief introduction to ASSISTments, and our decision to focus on improving its feedback, we set to work detailing what our proposed changes to ASSISTments would be

for our first pitch to three other IQP teams. Professor Beck assigned the task of informing the group of the general idea of the project and describing the big design decisions we saw, as well as some possible implementations we were considering.

There are two capabilities of ASSISTments that are important to our original design. One is that ASSISTments has a record of what the student knows. In other words, it has the ability to gauge each student's proficiency in a particular subject, even if it is not being utilized at the moment. The second assumption is that there is a way in the ASSISTments platform to determine the difficulty of each problem. One way in which it might compute the difficulty of a problem automatically is by recording the percentage of students which answer the problem correctly, and base difficulty on this number. Both of these assumptions were explained to the other groups in our presentation of Design 0.

2.1 Design Details

Our goal for Design 0, as laid out in our presentation, was to implement several forms of feedback. These forms included positive feedback that encourages learning, suggests learning material, and is specific to the student. We postulated that the first two points above might be accomplished by implementing the third. If provided with more personalized, individually tailored feedback, as is often seen in modern video games, the positive feedback might further encourage learning, and the "negative feedback" would hopefully have whatever advice necessary to start the student down the road to a correct answer in the future.

2.1.1 Custom Feedback

In an effort to provide specific details of how the feedback in ASSISTments could be specific to each student, we created examples showing what kind of written feedback a student might receive for answering a question correctly or incorrectly for three cases. The first example was the type of feedback ASSISTments should give to a student deemed to have a "minimal knowledge" of the subject matter at hand. The second was the case of an average knowledge student, and the third was with a high knowledge student.

Table 1 – Design 0 suggested feedback improvements

Student Knowledge	**Low**	**Average**	**High**
Feedback for *correct* answers	Give praise, suggest the student is learning the material	Give special feedback on difficult problems	Context specific feedback (consecutive correct answers, rewards, achievements)
Feedback for *incorrect* answers	Suggest looking at hints	Give special feedback on difficult problems	[no changes considered]

Table 1 is a table of the suggested feedback that could be crafted by ASSISTments to give students a more appropriate experience given their level of knowledge. Keep in mind that at this point our research was still evolving and in its early stages, so we had yet to confirm if any of these ideas held more merit than mere unanimous agreement within our group of four that they seemed appropriate. Our desired outcome of the feedback shown in Table 1 was twofold. Firstly, we wanted to encourage and educate students who have lower subject matter proficiency. We also want the students proficient

enough to regularly answer questions correctly to receive some form of context specific feedback. The actual particulars of this feedback will be explained in Design 0.5 and beyond.

2.1.2 Feedback Formula

We also designed a formula for ASSISTments to use in determining which of the 6 cells from Table 1 to present the student with. We first assumed that we have a measure of the student's knowledge from ASSISTments as a number from 0 to 1, ignoring how this number is obtained. We also assumed that we know the difficulty level of the problem. The feedback listed in Table 2 was our proposed feedback, with the given difficulty condition and answer condition combinations, where K is the knowledge value described above and D is the difficulty value of the problem.

Table 2 – Formula for determining feedback given answer condition and difficulty condition

Difficulty Condition	**Answer Condition**	**Feedback**
K < 0.5 * D (lower knowledge relative to the problem difficulty)	Correct	Praise ("Great job! That was a difficult problem!")
	Incorrect	Suggest that the student look at the hints, and break up the problem if they get it wrong twice.
K > 0.5 * D (higher knowledge relative to the problem difficulty)	Correct	Provide standard feedback ("Correct!")
	Incorrect	On the second incorrect answer, suggest looking at the hints, checking your work. Break up the problem if they get it wrong 3 times

As Table 2 shows, we wanted to give extra praise if the system thought the student had a lower chance of answering the question correctly. Unfortunately, this meant sacrificing the feedback for a correct answer given by a student who is deemed more likely to answer correctly. This student would only receive the standard "Correct!" feedback. It can also be seen in Table 2 that we were looking into increasing the number of incorrect responses available to a student before they are forced by ASSISTments to break a problem into steps (thus marking the problem as incorrect). We decided early on that it seemed unnecessary to immediately mark the problem as incorrect, and we allowed 2 or 3 attempts instead. Design 0.5 would simplify this idea, proposing a flat 2-attempt system, rather than the one detailed above, which gives higher proficiency students 3 attempts. We realized that this extra attempt was neither necessary nor justified by any real design rationale.

2.1.3 Point System

We also discussed the idea of introducing a point system during our Design 0 pitch. We wanted to use points, in one form or another, as a way to give students a sense of accomplishment and an additional incentive beyond just completing the assignment. We proposed that these points would be consistent from assignment to assignment and would need to be meaningful in some way, namely by rewarding students. In future designs, we would re-imagine these points as being hidden from the user and providing the framework for rewarding students with game-like rewards. This point system is explained in greater detail in Section 3.1.1.

2.2 Design Rationale

As explained in section 1.1, an important consideration for choosing which game-like element to add to ASSISTments was how difficult the element would be for teachers to use, and how difficult it would be to test and implement our incremental designs. Our other two initial ideas for game like elements, a game narrative and varying difficulty, would have been less desirable in this regard. Another factor is that textual feedback in education has a substantial amount of previous research. The only downside we could imagine to our decision to focus on feedback over a game narrative or varying difficulty is if ASSISTments does not really support the assumed ability to predict a student's knowledge and the difficulty of a problem.

2.3 Feedback Received

We received two pieces of feedback from our initial design. The first was Professor Beck saying that he liked linking points and feedback, as they both have the common theme of rewarding effort. He also wondered "How many points is something worth?" asking us to detail how many points each correctly answered problem might be worth. The point values are something we address in our next design iteration.

3 Design 0.5

After receiving feedback on Design 0, we began work on developing a second presentation for our fellow IQP groups. Our main focus for this design was to build on

the foundation we had established in the previous design. The primary goals were to provide more meaningful feedback to students, to be accomplished on two fronts: making feedback more personalized to the student, and to providing rewards for good performance that would help motivate the student to develop their skills.

3.1 Design Details

For Design 0.5, we continued to develop the features we had introduced in Design 0. This involved the exact specification of the points system mentioned in that earlier design, as well as a collection of rewards a user could earn by performing well. The implementation of the point system also led to setting more concrete guidelines in regards to what kind of feedback a student will receive based off of their performance.

We also introduced two new features in this design, both discussed in detail below. We added achievements in order to provide students with a long-term goal to consistently perform well, while the Personal Assistant Avatar was added to help add extra weight to the feedback. We also modified an existing feature in ASSISTments—the system currently e-mails parents when their child is doing poorly, so we decided to improve that functionality by notifying parents of strong performance by their child. This design culminated in a PowerPoint presentation to our fellow project groups.

3.1.1 Immediate Feedback

This design included the definition of a system where students' correct answers earned them points, which are in turn applied towards rewards that help them solve the current assignment. This system is focused on evaluating the actual performance of a student in comparison to their expected performance; for instance, if a poor student gets a particularly difficult problem right, they will receive an above-average number of points as a reward for going above and beyond. Meanwhile, a stronger student answering an easy question correctly will earn fewer points. Incorrect answers, while granting no points, have no negative effects on the point total. Utilizing the assumed knowledge and problem difficulty metrics from Design 0, the following table was designed as a guideline for the relationship between skill, difficulty and reward:

Table 3 - Design 0.5 Point Values and Feedback

Difficulty (0-1)	Student Knowledge (0-1)	Points	Feedback
0	1	10	"Correct" or equivalent phrase
0.25	0.75	25	"Correct"
0.5	0.5	50	Moderate Praise
0.75	0.25	75	High Praise
1	0	100	Highest Praise

In the table above, a difficulty of 0 is an easy problem, while a difficulty of 1 is a hard problem. A student knowledge value of 0 represents low knowledge, while a value of 1 represents high knowledge. The difficulty and student knowledge columns don't necessarily have to sum to 1; the point value is based on the ratio of difficulty to knowledge, and the values used are only there for the sake of example.

This system serves a dual purpose. Primarily, it places an emphasis on rewarding students who manage to solve problems outside of their current skill range. This helps the system to positively reinforce students who make an effort to strengthen their skills. However, it also helps the weaker students to learn the material and complete the assignment—a lower skill level means that the student will earn rewards (described below) that aid him

in the problem solving process, giving the student aids to help figure out particularly difficult problems.

Due to the fact that both measure student effort, these point values are directly linked to the level of feedback a student will receive. Particularly enthusiastic feedback is tied to high point values, while more neutral feedback is associated with lower point values. The explicit point values and totals are hidden from the end user. The desired outcome of this is that students connect highly positive feedback with earning more rewards. The feedback for correct answers is fairly general for the most part, although feedback on the upper end of the point scale may make a note of commending the student for their effort (i.e. “Great job! That was a tough one, you must be working hard.”). (Mueller and Dweck 50)

Table 4 - Design 0.5 Rewards

Condition	**Reward**
Every 600 points	Free Hint
Every 850 points	Retry Problem
6 consecutive correct answers	Skip a problem
3 passed assignments	Certificate E-mailed to parent

Table 5 - Design 0.5 Account Rewards

Condition	**Reward**
Completed 5 assignments	Badge
Completed 1 class	Trophy

There are three rewards available that directly affect the current problem set: the option to retry a problem without any penalty, the option to be given an additional hint without any penalty on a problem, and the option to skip a problem without any penalty. Retries and hints are designed to give students the ability to work through a difficult problem without having to forfeit credit on that problem (at the time, the ASSISTments system would give no credit if a student used a hint or got the problem wrong more than once). A hint becomes available every 600 points (about 12 average difficulty questions correct by an average student), while a retry becomes available every 850 points (about 17 average difficulty questions answered by an average student). These values are balanced to be low enough that students can earn multiple rewards per assignment, but high enough as to not trivialize the assignment.

The "skip a problem" option, however, should not be assigned through points—this may lead to the unfortunate outcome of a student completing the first part of an assignment with ease and earning the reward, and then using it to completely avoid problems outside of their current skill level. Instead, the skip is made available after completing 6 consecutive problems correctly, establishing it as a reward for students who already have a mastery of the material. The skip reward allows exceptional students to save time by skipping problems for which they already possess the necessary skills.

3.1.2 Rewards Outside of the Problem Set

The second set of rewards concerns those that have effects noticeable outside of the current problem set. These rewards are less oriented around individual problem performance, instead focusing on the student's performance on the assignment as a whole. For this design, these rewards are concentrated in two areas—achievements and correspondence with the parents (progress reports and certificates).

Achievements are linked to a student's account. Badges are awarded every 5 consecutive completed assignments, while trophies are given at the culmination of each passed class. These numbers were selected as to allow the achievements to be common enough to provide frequent reinforcement, but infrequent enough to prevent them from losing their value. These achievements can be accessed on an account page, where they will be represented by an image and a short description of how it was earned.

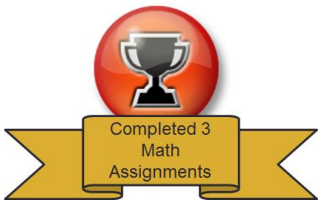


Figure 4 – Example achievement image

Achievements are cumulative and are granted each time a student completes a course or a required number of assignments. There is also flexibility to allow teachers to add their own achievements, allowing them to put an emphasis on areas they feel are important. We significantly update our definition of achievements in Design 2.

Parental correspondence is already a feature of ASSISTments; however, the current system will only contact a parent to inform them of notably negative performance such as missed or failed assignments. This design adds in correspondence due to positive performance through the addition of certificates and progress reports to the parents. Certificates are e-mailed to a student's parent when he or she completes and earns a passing grade on 3 consecutive assignments. The certificate is printable and contains the student's name, the subject the certificate was earned in and the date it was earned. These certificates are aimed towards younger users, and can be disabled for age groups that would not wish to receive them. This is another feature we change in Design 2.

Figure 5 – Example certificate

The design also included the addition of progress reports as a form of parental correspondence. These progress reports will be sent out on a weekly basis for each class, and will contain information on the student's performance in each assignment due over

the course of that week. These reports contain elements of both positive and negative feedback—positive progress reports reward a student's hard work by demonstrating the success to their parents. Meanwhile, the threat of a parent being informed of a student's notably poor performance or lack of effort serves as a tool for getting that student to put the appropriate amount of effort into their assignments. The progress report is more suitable for students who might be too old to find a certificate of achievement an appropriate reward; it serves a similar purpose of rewarding a student's hard work by telling their parents that their child is doing a good job.

3.1.3 Personal Assistant Avatar

Another major focus of this design was the implementation of a pedagogical agent referred to as the "Personal Assistant Avatar", or PAA. This agent was introduced to help simulate a relationship similar to that of a student and teacher, allowing the system to connect with the student on a more personal level. The PAA is responsible for almost all interaction between the user and the system during the problem sets. This includes presenting the initial problem, providing feedback on a provided answer, and helping a student walk through the steps of a problem if that student answers the problem incorrectly.

The PAA is inspired by the many similar "avatars" present in video games. It is not uncommon for a character floating on the screen to teach a user how to play the game, provide feedback, or give exposition. For example, in the popular real-time strategy game

StarCraft, selected units are given a portrait on the bottom of the screen. This portrait moves somewhat realistically and speaks to the player to confirm orders. The Nintendo 64 flight combat game *Star Fox 64* uses pictures of the player's wingmen to provide hints and tutorials. Our goal was to translate this use of avatars into the learning environment of ASSISTments.

Figure 6 – In *Star Fox 64*, Peppy tells the player to do a barrel roll to avoid damage (East)

Our proposed PAA is presented as a cartoon image of a teacher. It is present at all times during a session and communicates with the student through speech bubbles, facial expressions and movement. This helps it to establish a relationship with the student that

is closer to the teacher and student relationship, as opposed to that of a user utilizing an automated testing system.

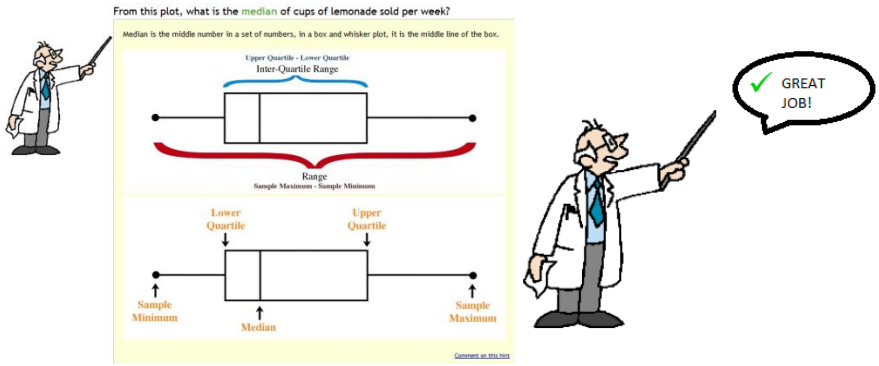


Figure 7 – Personal Assistant Avatar presenting a problem and providing praise

Although the PAA takes over the duty of presenting the problem, it does so utilizing the same problem structure as the current ASSISTments system. This allows teachers to use the feature without having to rewrite problem sets being used in the system. The PAA also changes its emotions based on interactions with the player. An incorrect answer causes the PAA to be sad, for instance, which simulates empathy. The desired outcome of this empathy is making the student feel less negative about answering incorrectly. Randomly guessing on problems, on the other hand, makes the PAA annoyed; the negative reaction from the PAA helps to motivate the student to cease the unwelcome activity and remain focused on their work. A correct answer makes the PAA happy and prompts a congratulatory message commending the student's effort, demonstrating a desire to see the student learn. This also helps to strengthen the relationship between the PAA and the student.

If a student answers a problem incorrectly, the PAA will help that student walk through the problem after it is broken down into steps. The PAA's ability to motion at relevant data keeps the student on task and directs the flow of information. The PAA can also provide links to useful sites (provided beforehand by the actual teacher) if a student is doing poorly, supplying the student with resources that they can use to help develop aptitude in the relevant skill.

3.2 Design Rationale

The primary focus of this design was to improve on the depth of feedback in ASSISTments. In the current system, feedback is minimal; students are told only if their answer is correct or incorrect, with no elaboration on why. This makes it rather difficult to extract meaningful information on what caused the answer to be correct or incorrect, which in turn makes it difficult for a student to know whether or not their personal strategy is working. Our main goal was to improve feedback to allow students to obtain meaningful information from it.

In a presentation on the topic of what makes good feedback, game designer Robin Hunicke describes a set of characteristics that help to make feedback engaging. These characteristics are: tactile, inviting, repeatable, coherent, continuous, emergent, balanced and fresh. They are all described as critical to "juicy" feedback—effective feedback that players seek to earn (Hunicke). We think our feedback has these characteristics.

The in-assignment rewards such as problem skips and extra hints are repeatable and inviting—the rewards can be earned multiple times if a student performs well enough, and the benefits provided by these rewards are strong enough to motivate a student to work towards them. These rewards are also coherent and emergent; they occur within the system as a reward for strong performance without breaking the flow of the assignment.

After we defined the PAA, we discovered a paper that discusses the value of a "proactive relationship" in which a teacher actively provides assistance to a student. The PAA aims to simulate this relationship in an effort to keep the student more engaged. (Jones)

3.3 Feedback Received

One concern noted with the design was that the system doesn't help students realize why they had earned a reward. While fairly frequent, the points-based rewards may come off simply as random if the players are not aware of the system. It is similarly worth informing the students that the skip is unlocked after answering 6 consecutive problems correctly. Although the points system should remain hidden, the awards should have a more detailed explanation of why they are earned. This issue is addressed in design 1.

Another issue was the frequency of the achievement certificates. While these certificates motivate the user, there were concerns that awarding these certificates too frequently

would make them feel meaningless and significantly reduce their use in motivating students. This was taken into consideration and resolved in Design 1.

One concern of Professor Beck was whether students should know how they are performing relative to the rest of the class; he felt that allowing a student to see their performance in comparison to that of fellow students could serve as a good motivation. The group decided that this was not a path we wanted to go down, however. We decided that the students are entitled to keep their performance private, and as such should not be required to have their performance posted to be compared to that of others.

4 Design 1

Following the feedback that was received from Designs 0 and 0.5, we set our sights on creating a demonstration which could be tested by students in order to determine which parts of our design would be effective and which wouldn't. Our continued research also turned up interesting finds on "animated pedagogical agents" in which several different studies showed that the "presence of an animated pedagogical agent has a strong, positive impact on students' perception of their learning experience" (Lester, Stone and Kahler 7) . In a study done at North Carolina State University, animated pedagogical agents were described as being animated agents which "inhabit interactive learning environments… and can exhibit strikingly lifelike behaviors." (Lester, Stone and Kahler 1) In another study, a proactive pedagogical agent was found to be more effective than a responsive one, with students achieving higher scores in assessments. The students also

demonstrated an improvement in the recall of information (Yanghee Kim 223) . The results of the study also indicated that students exposed to the high-competency responsive pedagogical agents showed higher scores in recall and indicated more positive attitudes towards the agents. For Design 1, we decided that the Personal Assistant Avatar should be a high-competency responsive type of pedagogical agent. Even though the proactive agent was shown to be better, we chose to use a responsive agent because we wanted to limit our design to something that is achievable. In order to implement a proactive agent, we would have needed to put considerable work into deciding how proactive the agent would be, how it would determine a need for intervention, and what it would provide the students. Although we hope that the PAA eventually becomes proactive, we decided not to focus on this aspect for our design.

4.1 *Design Details*

In order to see how the students would react to our design, we built a mock exam consisting of two different parts. The first part of the exam was an emulation of how ASSISTments currently runs with very minimalistic feedback, no rewards, and no incentives. The only feature available was that the system would break the question down into parts if the student got it wrong the first time. We used two multiple choice questions for the ASSISTments emulation. The first question required the student to find the range of a set of data, while the second question was much harder and had the student find the equation that was represented by a given graph and express it in slope-intercept form.

The second part of the exam was our own creation based upon what we would like to see in ASSISTments. The features which we added were:

- The Personal Assistant Avatar
- Ability to retry a question after the first wrong answer
- A free hint
- More variety of feedback expressed
- Ability to skip a question as a reward of doing well
- Receiving a trophy for completing an assignment
- Certificate being e-mailed to the student's parents.

This second part also consisted of two different questions. The first question asked the student to find the mode of a set of data, while the second question required the students to balance equations. We decided to make one question more difficult than the other so that we could see how the students would react when faced with hard questions, and how they felt about being given the ability to retry the question or use the free hint.

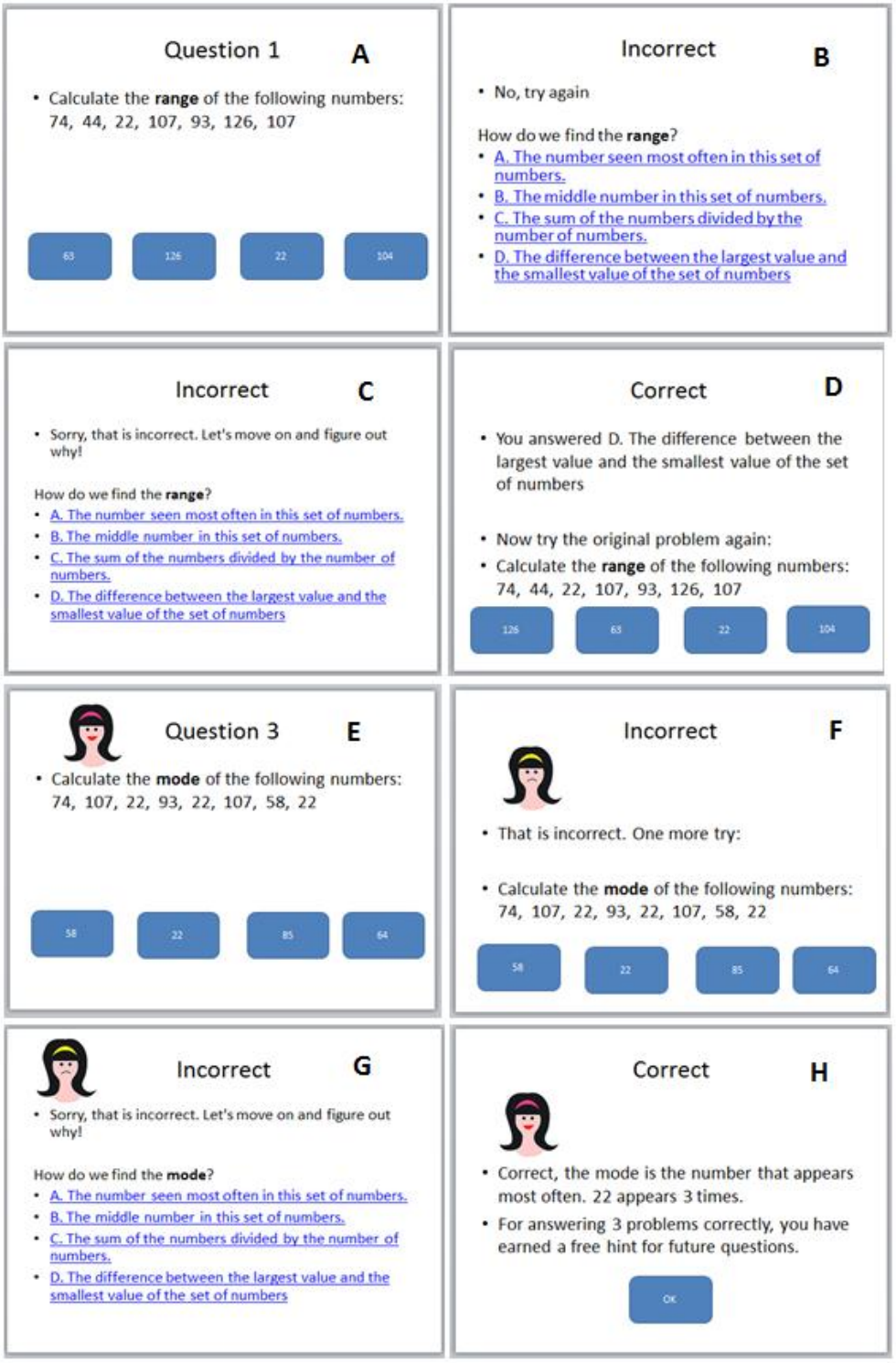


Figure 8 – Shows several different slides from our demo. Slides A-D are from part 1 of the exam. E-H are from part 2 and demonstrate the Personal Assistant Avatar as well as the other added features.

4.2 *Design Rationale*

One of the outstanding factors of academic performance in nearly all of our research was motivation and what drives it. To address motivation we came up with ideas of how to improve it. One method we came up with was using weekly progress reports for the students in order to keep track of learning accomplishments. In an article by Amy Woytek, she states that an effective way for students to recognize and track their improvement is by participating in self-assessment. She argues that through careful teacher guidance and practice, students can become effective judges of their own work. She also states that research shows that when students understand and apply self-assessment skills, their achievement increases and so does their motivation to learn. (Woytek 3). With Woytek's article in mind, we decided that e-mailing certificates to students and weekly progress reports to parents would be an effective method to show this progress. We wanted to gauge if students would react to this idea positively or negatively because there is little research on this topic relative to other aspects of our design.

The role of feedback was also very important in our readings on motivation and was one of the things we wanted to change about ASSISTments. After noticing the lack of feedback, we wanted to incorporate a system where we give students varying degrees of positive feedback depending on their progress, as well as including things such as telling students *why* they are correct or incorrect. In a publication from Curtin University about

providing feedback which encourages learning, we read that making feedback more personalized and letting the student know why he answered a question incorrectly would extend the ownership the students take over the feedback received. It also empowers the students and gives them a more analytical form of feedback about why an answer was just “good” and not “excellent” or “very good”. (Office of Assessment, Teaching and Learning). In an article by Kaylene C. Williams, she stresses that some of the key ingredients for improving student motivation are to ensure that the student feels success and accomplishment through feedback (Williams and Williams 4). Another successful key ingredient in feedback and improving student motivation was to connect the material being learned to a real world application to which the student can relate to.

The PAA was our way of bridging a relationship between the student and the work which they are performing. We wanted to create an environment where the student feels encouraged to do an assignment without feeling like the work they are doing is repetitive or tedious. We wanted to make each assignment more personal for each student and to have the student feel as if the study lesson was tailored for them. The PAA would be the bridge which would connect many of the functions we wanted to add into one single entity.

Since motivation also comes from intrinsic and extrinsic rewards, we wanted to reward the students with things such as being able to retry a question, or being able to skip a question as a reward. However we also wanted to see how effective the PAA would be in a classroom setting. In a recent study done at UMASS Amherst by Ivon Arroyo on the

impact that the sex of the tutor has on the students, results showed that low-achieving students (both male and female) benefitted greatly from the learning companions. On the other hand, high-achieving students had mixed results with data showing that high-achieving males did not receive any benefits from the learning companions. Results also indicated a higher benefit of learning companions for female students and also a significant improvement in motivation and confidence (Arroyo, Woolf and Cooper 3-5). While we weren't really interested in altering the sex of the avatar, we were curious on how effective it was with students.

4.3 Feedback Received

After administering the prototype to a total of 8 students, we received useful information regarding our design and our approach. In the table below, we paired the changes added to our prototype of ASSISTments with student feedback as well as noting how many students showed positive feelings toward each function. We also included any additional comments we felt were helpful in our evaluation of the prototype and for future designs. Since not every student was able to answer every single question, the student approvals in the table are only based on those that answered.

Table 6 – Student approval and comments of functions which were added to the prototype

Function	Student approval	Comments
Praise on difficult Questions	6/6	Helpful if system also scolded you for getting easy questions incorrect
Ability to retry a question after the first attempt	6/6	
Free Hint	6/6	Students felt like it was earned rather than deserved
Ability to skip a question as a reward of doing well	2/7	Students felt it was unfair and not beneficial
Receiving a trophy for completing and assignment	4/5	Wanted to show trophies off. Felt like they were earning something other than a grade
Weekly report being e-mailed to the students' parents.	7/8	Felt it was encouraging them to be successful if parents were involved. Some felt that poor results shouldn't be highlighted in weekly report.
Certificates for students	5/7	
Personal Assistant Avatar	7/8	Students liked idea of it

In general, all the students liked the idea of ASSISTments congratulating them for getting a difficult problem correct. One student also mentioned that it would be helpful if the system is condescending if the student gets an easy question incorrect. This is a feature which we would like to continue to improve on in later designs.

The ability to retry a question was also welcomed by the students with 6 out of 6 students for it. The students gave no additional feedback about this feature. However, after presenting our results to Professor Beck, we discovered that ASSISTments has already

considered this and is running several test pilots in which students are able to retry questions after the first attempt. Seeing that the above feature is already being tested, it might be better in future designs to focus on the other functions we would like to see added.

Our choice of giving a free hint to students for good performance was also well received, with 6 out of 6 students showing approval. Students claimed that they felt the hint was earned rather than deserved and saw it as a helpful way for them to work with harder problems. We agree that this feature is necessary and we should continue to improve on how it would be provided to students. It is particularly worth looking into whether it should be rewarded or if students should always have a free hint available.

The ability to skip a question, on the other hand, was not well received by students, with only 2 out of 7 students approving it. Most students felt that the ability to skip a question was the equivalent of cheating and no one would benefit from it. Other students felt that it promotes being lazy and that it would only allow others to avoid topics that they are not good at. Because of the negative attitudes toward skipping, we contemplated whether this feature should be removed from our design. However, we decided that the amount of data we received on this was inconclusive and would like to test it out with a different student group before making any decisions. We reach a compromise in Design 2.

Being able to receive a trophy for completing assignments was also welcomed by students with 4 out of 5 students supporting it. Students saw the trophies as a useful

reward when compared to just receiving a good grade. Some students also showed interest in showing off trophies for work that they have accomplished. We felt that the trophies were a successful way of providing positive feedback to students for doing well and it is another feature we would like to improve upon.

Sending a weekly report to parents was also well received by the students, with 7 out of 8 students approving it. Students commented that having the parents involved in their education was encouraging for them and motivated them to do better. However, some students also showed hesitation when asked if poor results should also be highlighted in the weekly reports. Others mentioned that it would be beneficial to highlight both types of results. We feel that having the parents involved in the students learning will have a positive impact on students. Because our initial prototype for the weekly reports consisted of just the survey question, we would like to flesh out how it would operate in future designs.

Rewarding students with certificates for completing assignments or topics in a course was also well received with 5 out of 7 students approving it. Most students did not provide any additional feedback on the certificates; however, one student mentioned that this feature was "Cool but unnecessary." This feature could prove helpful to certain groups of students and we would like to continue improving on it.

Our last added feature, the Personal Assistant Avatar, showed mixed results. Although 7 out of 8 students approved it in our survey and showed positive feedback, we thought that

our presentation failed to demonstrate the effectiveness which we attribute to it. Our design for the PAA was too simple for it to be effective. The students were not really interacting with the Personal Avatar but rather just reading the questions. Because our first prototype of the PAA was in the form of a picture of a head, it was not significant enough for kids to notice. We would like to modify it so that students are more likely to interact with it and notice it.

In future designs, we would like to make the avatar more dynamic and capable of catering to a student's needs. We also wanted to give the avatar more emotions to express. By adding emotions, we wanted the PAA to empathize with the student based on interactions with the system. For instance, giving the student a thumbs-up and a large smile for completing an assignment successfully or an unhappy face for getting many questions wrong is something which could encourage the student. Since the Personal Assistant Avatar is supposed to be as involved as possible, we wanted it to be able to give hints if it thinks the student needs it. This need can be gauged by noting a second attempt on a question or the fact that the student has been idle for a long time. The PAA should point students to other websites for background information on the current topic. The questions and hints should be incorporated in large speech bubbles emanating from the PAA. All of these changes would further integrate the PAA into every aspect of ASSISTments.

The lack of good artwork could also affect the effectiveness of the PAA and it is something which we would like to see improved upon in future prototypes. Another

change we would like to see is to make the avatar a full character rather than just a floating heading on the screen. Several articles we read also mentioned that the sex of the avatar could have different effects on different groups of students. (Arroyo, Woolf and Cooper 3-5) In future prototypes, we would like to research this further and see if having a male or female avatar would make a difference or if the option to have either gender should be added to the system.

5 Design 2

Taking the feedback we received in Section 4.3 of Design 1, we started to develop our final design. This design details what our next design iteration might look like if we were to factor in the research we did during Design 1, and the feedback we received on all of the designs. This section is a comprehensive summary of all of the new features we want to add, including those that are not unique to this iteration.

5.1 Feedback

5.1.1 Textual Feedback

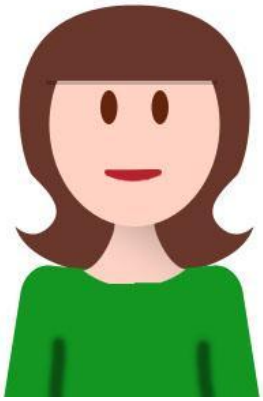
For Design 2, we wanted to improve how ASSISTments provided encouraging feedback to students. Currently, ASSISTments would show a “Correct!” or “Incorrect!” on each problem and would provide nothing in way of encouragement. In Design 2, as part of integrating the PAA, we wanted to provide much more personalized feedback depending on several different behaviors from the student. Many of the educational papers which we

have reviewed mention that in order to improve motivation in students, feedback has to be improved by making it more personalized. In Section 4.2, Amy Woytek argues that self-assessment allows students to be motivated and achieve more academically. By giving students more personalized feedback, we assist the students in self-assessment and hope to see results. These elements are expanded upon further in Table 8 of Section 5.1.2. We also explain how ASSISTments should provide feedback on why the student was correct or incorrect in their answer in Section 4.2.

5.1.2 Personal Assistant Avatar

As part of Design 2, we decided to make several changes to the PAA. From Design 1, we learned that our mockup did not effectively represent what we wanted to achieve with the PAA. Consequently, we decided to give it a facelift and build another mockup with a better implementation. As part of making the PAA more dynamic we decided to give it more emotions to express. We also made it more responsive to a student's needs by offering hints, providing the questions to the student, and pointing to external websites for help. Another change we wanted to make with the avatar was to make it so that it is no longer just a floating head. Instead, the upper torso is visible, and the avatar might gesture or point to questions.

Table 7 - Design 2 PAA Images

Emotion	Image	Description
Neutral		The student has just started the assignment. Also used when the PAA is providing a question.
Happy		The student has answered a question correctly, earned a reward or achievement, or has finished the assignment.
Sad		The student has answered a problem incorrectly. Used when the student is still perceived to be trying.

Emotion	Image	Description
Mad		The student has answered a problem incorrectly. Only used when it is clear that the student is guessing or rushing.
Confused		The student answered a problem incorrectly when ASSISTments thought the student would know. Also used when the student seems to be stuck, and the PAA suggests using a hint.

As Table 7 shows, we created 5 emotions for the new PAA to convey. Each image and associated emotion attempt to create an empathetic agent – one that understands and reacts to what the student is feeling. This helps the user maintain motivation, as Yanghee Kim says: "A [Pedagogical Agent] should respond to or deal with the learner's [emotion or desire] and flexibly adapt its affect to the learner's in order to motivate the learner." (6)

Using these emotions, we were able to create a table of how the PAA would react to a variety of potential situations that could occur during use of ASSISTments:

Table 8—PAA responses to various situations

Situation	PAA Example Feedback	PAA Mood
Student answers easy question correctly	"Correct!"	Happy
Student answers easy question wrong	"I'm sorry, that's incorrect. Be a little more careful next time."	Sad
Student answers difficult question correctly	"Good job! That was a tough one, you must be working hard!"	Happy
Student answers difficult question wrong	"I'm sorry, that's incorrect."	Neutral
Student uses hints and answers difficult question correctly	"Well done! Dealing with a hard problem step-by-step makes it much more manageable."	Happy
Student answers incorrectly, but uses breakdown to discern correct answer	"Good work! We can break down a problem we're not sure about to figure it out."	Happy
Student idle for an excessive amount of time	"We should get back to work when you're ready."	Confused
Student attempts problem without reading (within ~5s of page load)	"You should take your time to make sure you understand the problem before attempting it."	Mad
Student rushes through hint section to get to the answer at the end	"This isn't very helpful. Take your time to make sure you understand each step of the problem!"	Mad

The PAA reacts very positively when it detects that a student is putting in effort to learn the material, based off of findings stating that effort-based praise is more beneficial than intelligence-based praise (Mueller and Dweck 48). An example would be a student answering a problem incorrectly but then walking through the broken down problem to discover the correct solution. Although the student answered the question incorrectly, the

PAA provides strongly positive feedback stressing how it is pleased with the student solving the problem in that fashion. Similarly, the PAA will become disappointed and tell the student to work harder or pay more attention if that student incorrectly answers a question that should be easy for him or her. The PAA will become angry if a student tries to rush through a problem set by "gaming" the system (e.g. clicking through the breakdown to see the answer or rapidly guessing an answer); this kind of behavior has been proven to significantly hamper development (Woolf, Burleson and Arroyo 136-148), so the PAA will discourage it.

5.2 Rewards

5.2.1 Game-Benefit Rewards

In section 3.1.1 we discussed how the user accumulates points to earn rewards. This system is still in place for game-benefit rewards, but the trophy and badge system has been changed. Table 3 shows the point values for each type of problem, and Table 4 shows the values at which the rewards can be reached. The skip and hint rewards are restricted to one assignment – they do not carry over to subsequent assignments. This is so each student starts the assignment under the same conditions and no one has an unfair advantage.

5.2.1.1 Hint

After reviewing our results from the ASSISTments mock-up in Design 1, we decided that the hint is a very useful reward and motivational tool for students. For Design 2, we

wanted to use the PAA to present hints. Not only would it present hints when asked, but it would also proactively remind the student that they have a free hint if the system thinks the student is stuck. This should be more responsive to the student's needs. For example, if the student attempted to answer a question twice but was unsuccessful and appears to be having difficulty, the PAA would say, "Remember, you have a free hint you can use."

5.2.1.2 Retry

The retry was also another important tool we felt needed to be included in our design. At the start of this project, ASSISTments only provided the student with the opportunity to answer a question once. If the student answered incorrectly, the system would then break down the question and automatically assume that the student did not know how to complete the problem without breaking the problem down into smaller parts. This does not provide any allowance for small mathematical errors or common typing mistakes. To fix this, we wanted to provide a second chance to answer the problem. That way, they aren't immediately forced to work through the problem breakdown. However, we discovered that ASSISTments' maintainers added this functionality since we first envisioned this change.

5.2.1.3 Skip

As part of rewarding the students for doing well, in Design 1 we decided to implement a skip function which would be awarded to the student for doing well on an assignment and could be used to skip a single question without being punished for it. Although the feedback we received for this feature was mostly negative, we think that this is a good

reward for students and would like to further study if it is effective or not. The disdain for this feature may be explained by the demographics of our focus group, since they belonged to an after school math club and were likely highly motivated students. To address the issue of skipping questions which may be important to the rest of the assignment, teachers can mark questions as unable to be skipped, or turn off the feature completely. Unlike the hint, the PAA would not proactively remind the user that they can skip the question. We chose for the PAA to not remind students about their skips so we didn't make the impression that the avatar encouraged students to skip problems.

5.2.2 Certificates and Weekly Updates to Parents

After receiving a significant amount of positive feedback on certificates and weekly updates, we knew that this was an important way to not only get the parents involved in the student's learning, but to also improve student motivation.

For Design 2 we wanted to implement the certificates as a low cost solution to improving motivation. We also want to clarify what certificates are used for. Certificates would be awarded upon reaching some long-term goal, like completing 10 math assignments. We decided to make certificates harder to get so that students would not inundate their parents with certificate emails, and to make them more distinct from trophies. They would be saved to a student's account on ASSISTments for later viewing or printing. As a minor note, they should be customized appropriately for the age of the student; cute cartoon clip art may fit for a first grade student, but not for an eighth grader.

The weekly updates are another useful tool for getting parents more involved. Although ASSISTments already provides updates to parents when a student has not completed their assignments, we also wanted to reward students who are self-motivated and perform well. The weekly updates, apart from saying what assignments the student has completed, would highlight any positive characteristics the student has shown, whether it be completing the assignment in record time, receiving a top score, completing a hard topic without using hints, and so on.

5.2.3 Achievements

Another tool from Design 1 which we felt deserves to be looked at more carefully in Design 2 is the use of achievements. Like the certificates in Section 5.2.2, trophies will be a type of reward to students for doing well. However, our vision of achievements in Design 2 has become more concrete. We felt that the point of having an achievement was so that it could be shown off to peers and be used as markers for accomplishments. With this in mind, we wanted to change ASSISTments so that students would have an achievement page, visible to all other users, and showcase any achievements the student has earned through their progression of ASSISTments. Achievements are split into two types: badges and trophies. Badges are used for things specific to an assignment, like answering a problem quickly or correctly answering many consecutive problems. Teachers can optionally choose which badges can be earned for an assignment. Trophies are more structured across ASSISTments and are used for things like completing a number of assignments or finishing a class. The system can easily define trophies automatically.

5.3 Mockup

To help with visualizing most of these changes, we created a mockup of ASSISTments with our new features in action. Compare this to Figure 1 in the introduction, which depicted ASSISTments as it was before our changes.

In the mockup, the student has just struggled through a difficult problem. The PAA recognizes this and empathizes by displaying a sad face. The PAA now "asks" the student the next question instead of just having the question displayed plainly. Notice how the border around the question has been appropriated for use as a speech bubble metaphor by adding a tail near the PAA's mouth. The student earned a free hint earlier in the assignment, which they can use by clicking the new "Ask the tutor for a hint" button.

In this case, the student answers the question correctly on their first try. Because this was unexpected based on the student's previous performance, the PAA displays a very happy face. As part of the textual feedback system, the PAA congratulates the student and comments on how they must have worked hard on that problem. Below the congratulation message, the PAA explains *why* the student was correct. On top of all of this, the student has earned an achievement for completing three math assignments.

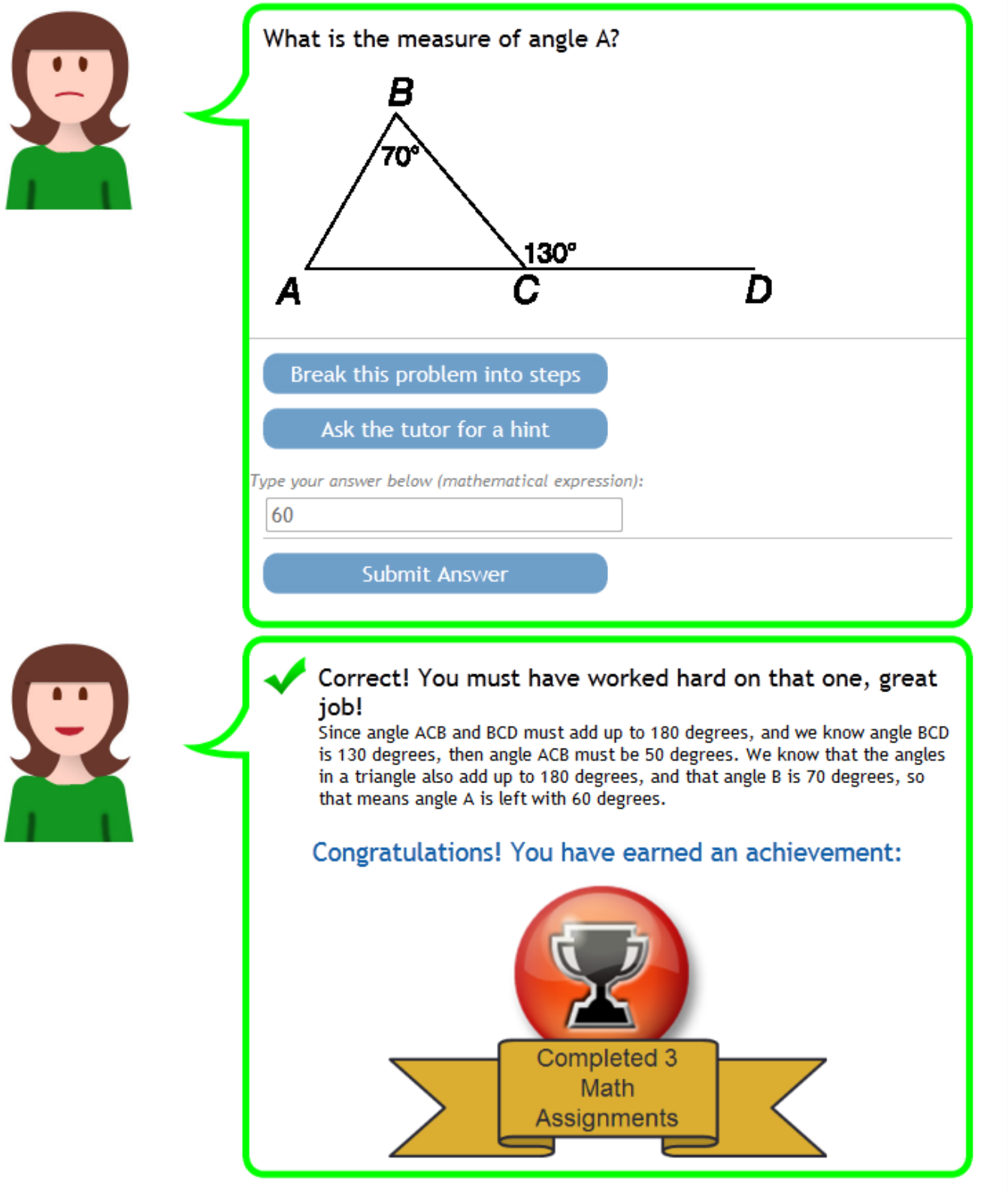


Figure 9 – A mockup of an answered problem in ASSISTments, showing many of our proposed changes

6 Future Work and Conclusions

Our design has brought up many questions that could be pursued in future work. One example is how specific textual feedback affects the student on a word-to-word basis. We had to come up with concrete text to put on the screen, but could not find any existing research on the effects of certain words or phrases. The best we could find was a few documents regarding general attitudes to convey and examples used in a classroom setting, but nothing more specific than that. This makes it hard to justify the use of one phrase over another. Such future work would consider the effects of phrases like “Good job” vs. “You did great”, or “You can do better” vs. “You need to work harder”, and so on. There may be no significant difference between such phrases, which would be a valuable conclusion itself.

During Design 1, we decided that we wanted to tell the student why they were correct or incorrect. Such behavior is very difficult to implement, since ASSISTments would need to be able to analyze each problem and answer to deduce common misconceptions the user may be experiencing. For practicality reasons, we limited this to feedback that the teacher would have to provide. In the future, determining how to have ASSISTments provide the ideal feedback would be an excellent topic to pursue.

We also would have liked to delve deeper into the effects of specific avatar properties regarding its appearance. Could we elicit certain behaviors by making the avatar wear a

certain color, have a different facial structure, be attractive or unattractive, or be of a particular race? Is it even ethical to play up to students' believed stereotypes about people's appearances in order to improve their learning experience? We know that the avatar's gender has an effect on student perceptions (Kim 6), but does it go further than that?

The only way to really prove that the elements of our design are beneficial is to implement them in ASSISTments and empirically test them. To do this, one might implement a single feature (say, variable textual feedback) and only expose it to half of ASSISTments' classes for some period of time as an A/B test – a form of testing that's increasingly popular on the web (Kohavi, Longbotham and Sommerfield). During the testing period, keep track of the change in statistics like average grades, rate of question completion, measures of engagement (idle time, mouse activity, etc.), or any other relevant data. At the end of the testing period, compare statistics between the control and experimental groups to see if the new feature made a positive difference. It would also be useful to solicit qualitative feedback from students and teachers regarding the new feature, since it may have an impact in the classroom or at home that cannot be measured by ASSISTments itself. This is especially important for features like certificates being sent home to parents or achievements which may create competition between students.

Regarding achievements, we are not entirely sure how they will turn out in a classroom environment. We know that achievements are addicting and motivating for video games, but will it really turn out the same in a classroom environment? One side might claim that

the competition created between students by giving the best students an award would be especially motivating. If a student sees that his friend has an achievement, he will try to get it as well, along with more achievements to show his superiority. However, the other side can claim that the system could lead to feelings of inferiority among those without achievements, or that the competition between students can be destructive or hurtful. Perhaps the best way to answer this question is to perform a long-term study of a class that uses the achievements system.

Another limitation of our work is that the user study was restricted in scope. We didn't have time to actually add our proposed features to ASSISTments, and had to settle for simple PowerPoint slides that emulated its behavior and a quick interview. Because of the limitations of the platform and how little time we had with the students, we couldn't demonstrate our textual feedback system. Everything worked out adequately, but the results may have been more convincing if we had used ASSISTments itself. The students were also from a very narrow demographic: middle school students participating in an after school math program who, for the most part, had already used ASSISTments. It would be more useful to test our design on students from a variety of backgrounds and grade levels in the future.

Despite these shortcomings, we came up with an actionable design proposal that synthesizes current research from the fields relevant to ASSISTments. We also gained valuable feedback from the platform's target audience and incorporated it into our design.

We put forth a mechanism for textual feedback that changes based on the difficulty of the question and the knowledge of the student. Feedback can be tailored to fit the student, praising them for unexpected success or encouraging better performance for an unexpected lack of success. This feature should be a big step up from common static feedback like “Good job!”, and it requires no extra effort on the part of the teacher.

We defined a number of rewards for good performance from students to act as another feedback mechanism. One reward type is achievements, which don’t have any real functionality on their own, but they allow the system to recognize notable behaviors and give the student additional motivation and encouragement. The competition created by achievements may drive the student to perform even better. Other rewards are certificates and progress reports emailed to parents, free hints for problems, and the chance to retry an incorrectly answered problem.

The final major element is the Personal Assistant Avatar. The PAA is a simple character on the page in ASSISTments which presents questions, expresses the variable textual feedback, and offers help by pointing to relevant learning material as needed. It also empathizes with the student through facial expressions and other body language. The student’s current mood can be approximated by their performance and by measuring aspects of their interaction with the system. The PAA provides a learning environment that is closer to an actual classroom or a session with a private tutor. Our research indicates that this will improve student motivation and their subjective satisfaction with ASSISTments.

This design will greatly improve the feedback in this system that thousands of students use daily to complete their homework or in-class exercises. After responsible user testing, we hope that our proposed changes will be implemented in ASSISTments in the coming years.

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9 Appendices

9.1 Appendix A – Group Presentations

Group 4: ASSISTments

Glen Lovett, Andrew Hurle, Ian McNeil, Arben Koshi

1

ASSISTments

- Web based teaching software
- "Generic system for any subject from math to English to science"
- Example problem

2

ASSISTments

- Has a record of how much a student knows
- Knows the difficulty of each problem
- This will be important later

3

Feedback in ASSISTments

- Currently, feedback is minimal
- Correct answers: "Correct!"
- Incorrect answers: Context specific, created by teachers
- Same feedback for all students

How to Improve Feedback

- Want positive feedback to encourage learning
- Feedback on incorrect answers should ensure the student stays motivated, and should suggest where to turn for help
- Specific to the student

Worked example

- Student with minimal knowledge of subject matter: Joe
- Student with average knowledge: Scott
- Student with lots of knowledge: Melvin

Joe

- Low knowledge student
- Correct answers: Give praise, suggest the student is learning the material
- Incorrect answers: Suggest looking at hints
  - ASSISTments has hints already

7

Scott

- Average student
- Currently:
  - ASSISTments prevents breaking down problems once answered correctly
  - Also forces student to break down problem after one incorrect answer.

8

Scott

- Increase number of incorrect responses
  - Specific number could be set by teacher
- We want to allow students to retry answering the original problem after each step
- Give special feedback on difficult problems

9

Melvin

- High knowledge student
- Context specific feedback:
  - Congratulate for consecutive correct answers
  - Give "achievements" for noteworthy grades or certain number of passed tests
  - Give opportunity to skip a problem after multiple consecutive correct answers

Determining Feedback

- Assumptions
  - We have some variable K that measures a student's knowledge as a number between zero and one
  - Another variable D measures the difficulty of the problem

Determining Feedback

- If $K < 0.5 * D$, and the student gets the question correct, then we give praise
  - "Great job! That was a difficult problem!"
  - "Congratulations, you're learning a lot!"
- If the student gets the question incorrect, we suggest that the student look at the hints, and break up the problem if they get it wrong twice

Determining Feedback

- If $K > 1.5 * D$ and the student gets the question correct
  - Provide standard feedback ("Correct!"), ignoring special cases for achievements
- If the student gets it incorrect
  - On the second incorrect answer, suggest looking at the hints, checking your work
  - Break up the problem if they get it wrong 3 times

13

Scoring

- Want notion of "points" to give student a feeling of accomplishment
- Provide an incentive beyond just completing the assignment
- Accumulated from assignment to assignment
- Provide rewards to students
- Need to be meaningful

14

9.2 Appendix B - Second Group Presentations

GROUP 4: ASSISTMENTS

Glen Lovett, Andrew Hurle, Ian McNeil, Arben Koshi

This week

- What we are focusing on
  - Assistments
  - Rewards and feedback
- What we don't want to do

What we want to do

- Describe improvements to feedback in Assistments
  - Immediate feedback system using points
  - Rewards
  - Personal Assistant Avatar
- Specify rewards
  - Intrinsic vs. extrinsic motivation

Point system

- Point values hidden from user
- Points are used to determine feedback
- Difficult question → Higher points → More praise
- The lower the knowledge of the student, the higher the points
- (Will also look at how other groups approach points)

Point Table

Difficulty (0-1)	Student Knowledge (0-1)	Points	Feedback
0	1	10	"Correct" or equivalent phrase
0.25	0.75	25	"Correct"
0.5	0.5	50	Moderate Praise
0.75	0.25	75	High Praise
1	0	100	Highest Praise

Rewards

condition	Reward
Every 600 points	Free Hint
Every 850 points	Retry Problem
6 consecutive correct answers	Skip a problem
3 passed assignments	Certificate E-mailed to parent

Account Rewards:

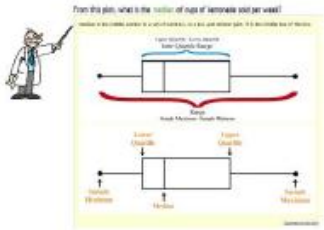
Condition	Reward
Completed 5 assignments	Badge
Completed 1 class	Trophy

Personal Assistant Avatar

- Introduce a PAA (intrinsic/extrinsic motivation)
- Creates *Proactive* relationship (Relationship Framework, R.D. Jones)

- PAA can show interest and provide support
- Establish and communicate learning goals

Personal Assistant Avatars



Feedback

- Example: high Praise

Feedback Guidelines

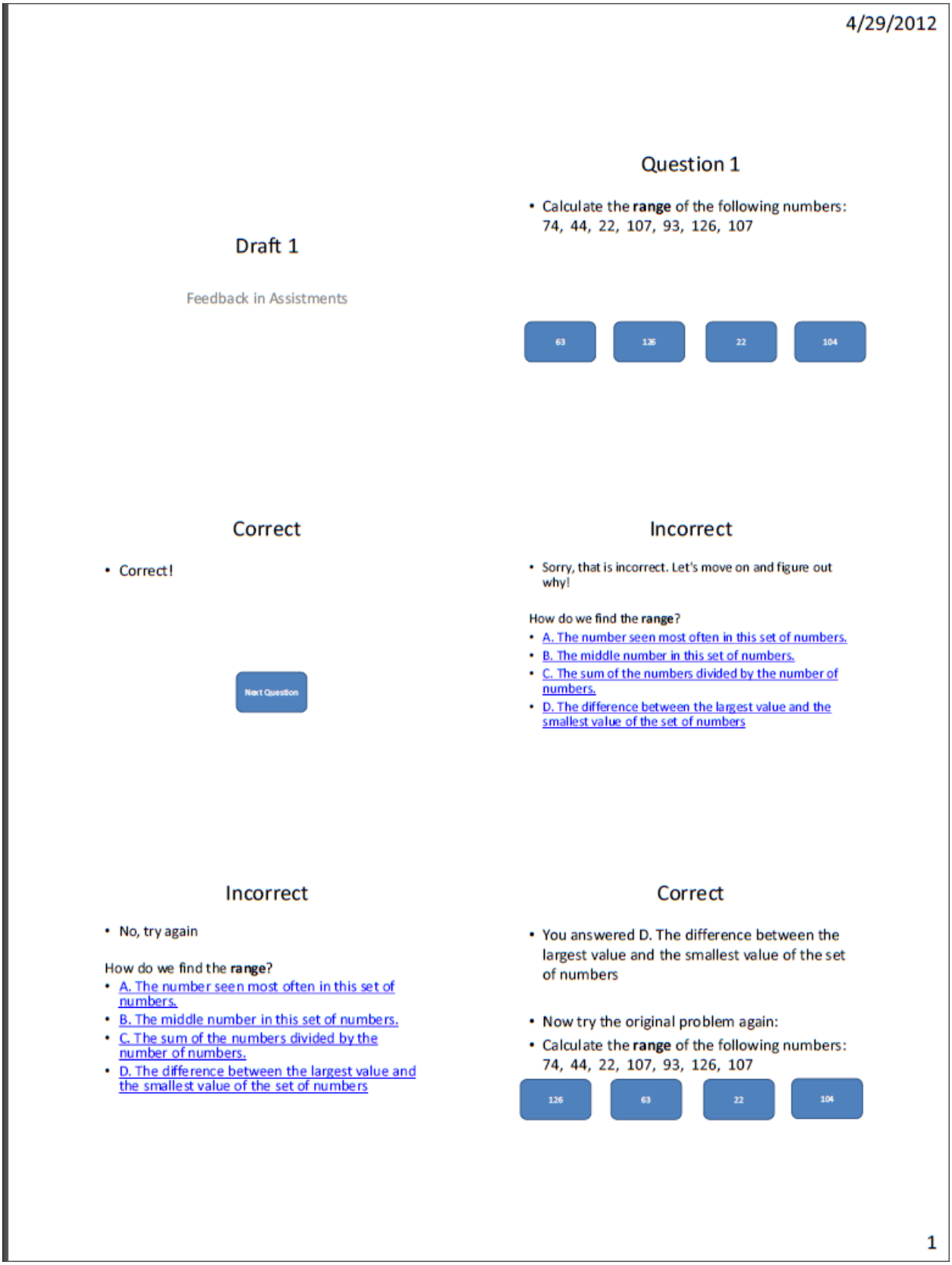
- Praise students for their effort, not for some innate intelligence (Mueller and Dweck)
  - Students who are praised for effort tend to challenge themselves, while students who are told they are smart have a high fear of failure

What we are not doing

- Not determining the subject matter
  - This is up to individual teachers
- Not customizing the avatar
  - Avatar is to make feedback/instruction more relatable
  - Outside scope of what we are looking into

Questions?

9.3 Appendix C – Student Mockup

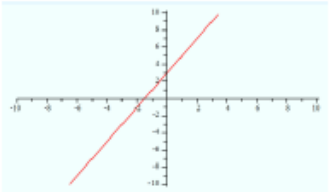


Incorrect

- Try again:
- Calculate the **range** of the following numbers:
  74, 44, 22, 107, 93, 126, 107

126 | 63 | 22 | 104

Question 2



- What equation is modeled by this graph?

3x + 2 | 2x + 3 | x + 3 | 3x - 2

Correct

- Correct!

Next Question

Incorrect

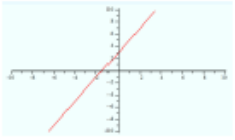
- Sorry, that's incorrect. Let's move on and figure out why!
- The slope of a graph is determined by:
  - A. change in X divided by change in Y
  - B. change in Y divided by change in X
  - C. change in X multiplied by change in Y
  - D. change in X minus change in Y

Incorrect

- No, try again.
- The slope of a graph is determined by:
  - A. change in X divided by change in Y
  - B. change in Y divided by change in X
  - C. change in X multiplied by change in Y
  - D. change in X minus change in Y

Correct

- You answered B. change in Y divided by change in X. Now try the original problem again!

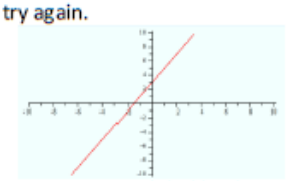


- What equation is modeled by this graph?

3x + 2 | 2x + 3 | x + 3 | 3x - 2

Incorrect

- Sorry, try again.



- What equation is modeled by this graph?

3x + 2 | 2x + 3 | x + 3 | 3x - 2

Introduce "Personal Avatar"


Question 3

- Calculate the **mode** of the following numbers:
  74, 107, 22, 93, 22, 107, 58, 22

58 | 22 | 85 | 64

Correct

- Correct, the mode is the number that appears most often. 22 appears 3 times.
- For answering 3 problems correctly, you have earned a free hint for future questions.

OK

Incorrect

- That is incorrect. One more try:
- Calculate the **mode** of the following numbers:
  74, 107, 22, 93, 22, 107, 58, 22

58 | 22 | 85 | 64

Incorrect

- Sorry, that is incorrect. Let's move on and figure out why!

How do we find the **mode**?

- A. The number seen most often in this set of numbers.
- B. The middle number in this set of numbers.
- C. The sum of the numbers divided by the number of numbers.
- D. The difference between the largest value and the smallest value of the set of numbers

Incorrect

- No, try again

How do we find the **mode**?

- A. The number seen most often in this set of numbers.
- B. The middle number in this set of numbers.
- C. The sum of the numbers divided by the number of numbers.
- D. The difference between the largest value and the smallest value of the set of numbers

Correct

- You answered A. The number seen most often in this set of numbers.
- Now try the original problem again:
- Calculate the **mode** of the following numbers: 74, 107, 22, 93, 22, 107, 58, 22

58 | 22 | 85 | 64

Incorrect

- Try again. Remember, the mode is the number seen most often in this set of numbers:
- Calculate the **mode** of the following numbers: 74, 107, 22, 93, 22, 107, 58, 22

58 | 22 | 85 | 64

Question 4

- $2x - 4 = 16 + x$
- What is the value of x? Click to Use free hint

20 | 4 | 8 | 10

Incorrect

- That is incorrect. One more try:
- $2x - 4 = 16 + x$
- What is the value of x? Click to Use free hint

20 | 4 | 8 | 10

Incorrect

- That is incorrect. One more try:
- $2x - 4 = 16 + x$
- What is the value of x?

20 | 4 | 8 | 10

Hint

- Try adding 4 to both sides of the equation
- $2x - 4 = 16 + x$
- What is the value of x?

20 | 4 | 8 | 10

Hint

- Try adding 4 to both sides of the equation
- $2x - 4 = 16 + x$
- What is the value of x?

20 | 4 | 8 | 10

Correct

- Correct, x = 20 as shown by simplifying the equation:
  - $2x - 4 = 16 + x$
  - $2x = 20 + x$ (add 4 to both sides)
  - $x = 20$ (subtract x from both sides)

Click to complete assignment

Incorrect

- Sorry, that is incorrect. Let's move on and figure out why!
- We can make this equation easier to solve by adding or subtracting terms from each side of it. Which of these equations is equivalent to our initial equation, $2x - 4 = 16 + x$?

$x = 20 + x$ | $2x = 12 + x$ | $2x = 20 + x$ | $x = 12 + x$

Incorrect

- Sorry, try again.
- We can make this equation easier to solve by adding or subtracting terms from each side of it. Which of these equations is equivalent to our initial equation, $2x - 4 = 16 + x$?

$x = 20 + x$ | $2x = 12 + x$ | $2x = 20 + x$ | $x = 12 + x$

Correct

- Good job! Now try the original problem again.
- $2x - 4 = 16 + x$
- What is the value of x?

20 | 4 | 8 | 10

Incorrect

- Try again. Remember, add or subtract terms from each side of the equation to solve for x.
- $2x - 4 = 16 + x$
- What is the value of x?

20 | 4 | 8 | 10

You are done with this assignment!

You have earned a Trophy for completing your first math assignment!

Survey Questions

- What did you think of the personal avatar?
  - Was it helpful?
  - Did it motivate you?
  - Were there things that you disliked about it?
- Did you like the free hint?
  - Did it help you?
  - Did you think earning hints is worthwhile? Why?
- Would you like it if the system congratulated you for getting a problem correct that it thought you wouldn't?
- How would you feel if your parents were told how well you did on these questions?
  - Would it motivate you to work harder?
  - What if they were only notified when you did poorly? Would this be motivating?
  - What if they were only notified when you did well? Would this be motivating?

- Would you like a certificate like this E-mailed to your parents?

- Would you like it if you were able to skip a question after performing well for several questions?
- Would you like being able to retry a problem if you have been performing well?
- Would you like the ability to earn trophies/achievements for performing well?

9.4 Appendix D – Student Questionnaire

Student Presentation Notes Sheet Game-like Tutors IQP Group 4 WPI

Student Path

Question 1:
Correct Breakdown Breakdown Incorrect Breakdown Correct Post-Breakdown Incorrect

Question 2:
Correct Breakdown Breakdown Incorrect Breakdown Correct Post-Breakdown Incorrect

Question 3:
Correct Incorrect Breakdown Breakdown Incorrect Breakdown Correct
Post-Breakdown Incorrect

Question 4:
Correct Incorrect Hint Breakdown Breakdown Incorrect Breakdown Correct
Post-Breakdown Incorrect

Student Comments

What did you think of the personal avatar? Was it helpful? Did it motivate you? Were there things that you disliked about it?

Did you like the free hint? Did it help you? Did you like earning the hint?

How would you feel if your parents were told how well you did on these questions? Would it motivate you to work harder? What if they were only notified when you did poorly? Would this be motivating? What if they were only notified when you did well? Would this be motivating?

Student Presentation Notes Sheet Game-like Tutors IQP Group 4 WPI

Would you like a certificate like this E-mailed to your parents?

Would you like it if you were able to skip a question after performing well for several questions?

Would you like being able to retry a problem if you have been performing well?

Would you like the ability to earn trophies/achievements for performing well?

Other comments or notes: