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Intelligent Scanner

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INTELLIGENT SCANNER

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To

Professor Joseph Beck, Advisor

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Abstract

In today's world, too much of teachers' time is occupied with tedious work, such as grading daily homework assignments and entering grades. These menial tasks distract teachers from their true purpose—teaching. The purpose of this project was to conduct a needs analysis for a tool to reduce the time spent on these tasks. We gathered and evaluated requirements for such a tool. The target user for this tool ranged from elementary to high school teachers. The main goal was to make it widely available for teachers, especially those in the public school system. We found that there was a large variability between different public schools, such as in technology literacy and school funding. This made it somewhat difficult to create a universal solution; however, there were commonalities that we could leverage.

Acknowledgements

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1. Introduction

In recent years, the idea of a paperless environment has been battling against that of the traditional paper environment. Both solutions have their advantages and disadvantages. Some of the advantages of a paperless environment include a more organized workspace, a document search functionality, and a reduced consumption of natural resources. On the other hand, a traditional paper environment offers tactile feedback and familiarity. The goal of this project was to explore the possibility of merging the two environments with the assistance of scanning technology. Mainly, we explored what approaches could be used to get the benefits of both environments, in order to create an organized workspace with quick information access that still offers the familiarity that teachers and students are used to in a traditional paper environment.

There are many potential benefits to merging the two environments. For example, if a student is falling behind in a class, how could a teacher identify the cause? The teacher could manually go through the gradebook and figure out the student's weaknesses. However, in a paperless environment, a program could assist teachers with this tedious task. For instance, a program could suggest the student's weak points based on his or her grades. This would allow teachers to respond more quickly to students who are falling behind in class because the causes could be more quickly identified. Moreover, teachers could have a digital teaching assistant that verifies students' homework and exam grades. Grading is time-consuming, but if the grading process is computerized, not only will grading be more time-efficient, but a software could also compile useful information from assignments and exams, such as question statistics and topic statistics. An example of a question statistic is, "How many students answered this

particular question incorrectly," while an example of a topic statistic is, "How did the class perform on questions related to this particular topic?" With this information, a software could create student reports detailing how well a student has done on a particular subject, such as multiplication or finding congruent triangles. These are some possibilities that can assist teachers with their daily routines, which can lead to higher teacher productivities.

2. Existing Technologies and Limitations

Optical Mark Recognition

Optical mark recognition or OMR is a way to capture human-marked data from easy-to-use forms. The most commonly used type of OMR is the Scantron (Figure 1). OMR is probably the most basic form of intelligent scanning technology. It was invented in the 1930s, and since then, it has been used extensively from elementary school to college and beyond for the collection of data, including data on exam performance, surveys, time sheets, and voting. The Scantron is a machine-readable piece of paper where marks are made for answers to multiple-choice questions. To analyze the responses, a specialized scanner is used to scan these slips of paper for a quick and effective analysis. OMR systems approach an almost one hundred percent accuracy rating, although there is a possibility of missing certain data during the scanning process or pages being accidently scanned in the wrong order, yielding incorrect data. The scanner takes about half a second to score one of these Scantron forms accurately (Scantron Corp, Scantron score: Scantron's New Test Scoring Machine!, n.d.). Although the process of using OMR is very efficient, it is limited to multiple choice questions and answers only. Moreover, the cost of OMR forms can be very high, for each sheet is sold anywhere from 10 to 19 cents each (Scantron Corp, Scanner & Forms Store, n.d.). This can become a problem in schools with little funding for paper necessities.

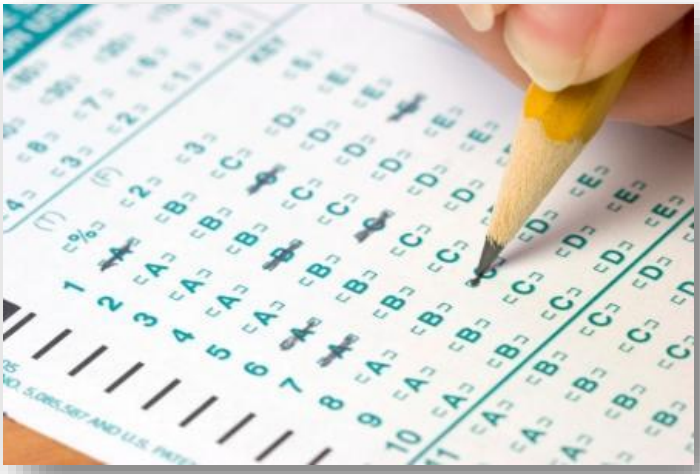


Figure 1. OMR form being used for exams

Scanning Characters (Optical Character Recognition)

The scanning of characters is more difficult than OMR, but it is not too complex for optical character recognition (OCR) techniques available today. Alphanumeric characters only consist of thirty-six different characters (A-Z, 0-9). Because there are a fixed number of alphanumeric characters, the recognition of these characters is relatively accurate. The clearer the imaging of these characters, the more accurate the OCR system will be. This type of technology is used by the police to scan license plates and by postal services to scan zip codes, in order to organize and analyze data more efficiently.

License plates all have a consistent format. All letters are of the same font and size, which eliminates idiosyncrasies. The consistent typeface further increases the accuracy of the recognition. Additionally, a license plate always has three to six characters, so the OCR systems look for the same image in every scan. These factors allow the recognition of license plates to

be very accurate. Postal services also have a specific format for postal codes of five digits (and occasionally nine digits). Consistency, along with a small set of numerical possibilities, simplifies the recognition process, because the software only has to be programmed to recognize a limited number of characters and a certain length of those characters. Although the technology might have to read handwritten numbers, it only has to detect the digits 0 to 9. Handwritten text does make this process more difficult, but the ability to analyze numbers and different fonts is feasible for scanner technologies.

Handwritten Text

The most complex scanning technology we have found was an automated grader of the SATs. The software was made by Educational Testing Service (ETS). This technology is very complex, because it is much more difficult to read handwritten essays than to decode a small range of numbers. There is no limit to the number of characters, the length of characters, or the style of writing. ETS's technology is not well known, and the information regarding this technology is not readily available. However, we do know that it is capable of scanning and processing handwritten essays, while simultaneously providing feedback in the form of grades. The technology is able to match words and phrases with each other by generalizing the meaning behind the text. It is able to piece together many types of linguistic relationships, including lexical entries with their respective semantic meanings. This technology is so much more complex than other technologies, because it has to read handwritten documents of undetermined font, size, and length. Handwritten documents, especially in the testing environment, can have bad handwriting, misspelling, or off-topic writing. The high inconsistency makes it more difficult to create a high accuracy tool. The chance that the

technology misinterprets a handwritten passage or falsely identifies a word is very likely. Although processing handwritten text increases the complexity of the scanner, with the right implementation, it can be done effectively. ETS has illustrated that it can be accomplished on a large scale.

How can existing technologies be applied

After looking at different existing technologies, we began to differentiate what computers could and could not accomplish. We concluded that anything dealing with handwriting, such as personal essays or short responses, would be overly complicated for our project. Therefore, we mainly focused on topics that did not involve handwriting. The history of OMR showed that any type of multiple-choice based response would be easy to process, document, and grade. Seeing that scanners can read license plates on moving cars and can process handwritten addresses for mail, we figured that it would be possible to scan and process simple short answers. The answers could be a simple numeric answer or a few word response. Numbers are much easier to process than letters because they only have a range from zero to nine. It might get difficult with more complex numbers such as decimals or fractions because the correct answer could be written in many different ways.

In addition to constraining responses, we would also need to use some kind of specially formatted paper to assist scanners with information processing. This would aid the technology, because the scanner would search certain areas for certain information. With the technology of scanning addresses and sorting mail, we also thought that it would be easy to scan students' names on homework assignments and exams. This is because the class list is known, so it gives

us a small set of possibilities to work with. Reading grades from a paper is possible as long as the teacher places the grade in a specified area on the paper. When it comes to actually grading work, the scanner would do best in math, because reading handwritten text is much more difficult than reading handwritten numbers of math calculations.

3. Use Cases

We attempted to imagine teachers' day-to-day tasks to come up with a list of tasks. We concluded that their major tasks are grading (homework assignments, quizzes, and exams), entering grades, preparing for future classes, and assisting students who may need additional attention. From the list of tasks, we came up with a list of possible tasks that could be accomplished or supported by today's technologies.

We explored many possible implementations for the smart scanner software and narrowed the possibilities down to three small use cases: a database of students' progress, an automated grading system, and an automated grade book. Each of these could aid teachers with necessary but time and labor intensive tasks. These use cases should increase teachers' productivities.

Specially formatted paper

Computers are very good at computing answers to complicated equations. However, it is very difficult for computers to comprehend images and audio. The concept of specially formatted paper is to tell computers what to look for on a sheet of paper filled with natural inputs, in this case: handwriting. Figure 2 and Figure 3 are examples of specially formatted paper. Figure 2 is a mockup of how students' homework might have to look in order to be processed by the scanner. The top section is used to identify the students and their grades. The rest of the paper is dedicated to students' work and answers. Students will have to put their answers in the box to assist the scanner. Figure 3 works the same way, but this would function as a simple coversheet that students use. The teachers could use the scanner to input the grades into the system automatically.

Automated grade input

The goal of automated grade input is to decrease the amount of time teachers need to process students' grades. Teachers must grade students' assignments and exams, but they do not have to enter those grades manually. Automated grade input would reduce the teachers' workload. The scope of this use case is for the scanner to simply read assigned grades on exams or assignments and enter them into the system. Teachers already spend a lot of time grading homework assignments and exams, so automating the input of grades into the system grants teachers more free time to do tasks that are more important.

Figure 3 is an example of how a coversheet or the first page of material to be scanned could be formatted. For this use case, we simply need to extract identification information,

such as the student's name and ID number. The example uses both name and ID number to increase reliability and flexibility. If the scanner cannot interpret the name, it can interpret the ID number, or vice versa. This method should decrease the amount of human intervention in case the scanner fails to interpret parts of the information. Additionally, this method is a built-in fault detection device, because in case of name and ID number mismatch, the scanner could flag the paper and alert the teacher. As for the grade, the scanner's software interprets the numerical grade and assigns it to the student. However, the software may occasionally enter incorrect grades into the system. Therefore, it needs to have some sort of built-in fault detection system. To remedy the situation, the software can assign a probability match for each entry, and if the probability is below a certain threshold, it must seek attention so that it will raise a flag, which teachers can later locate and correct.

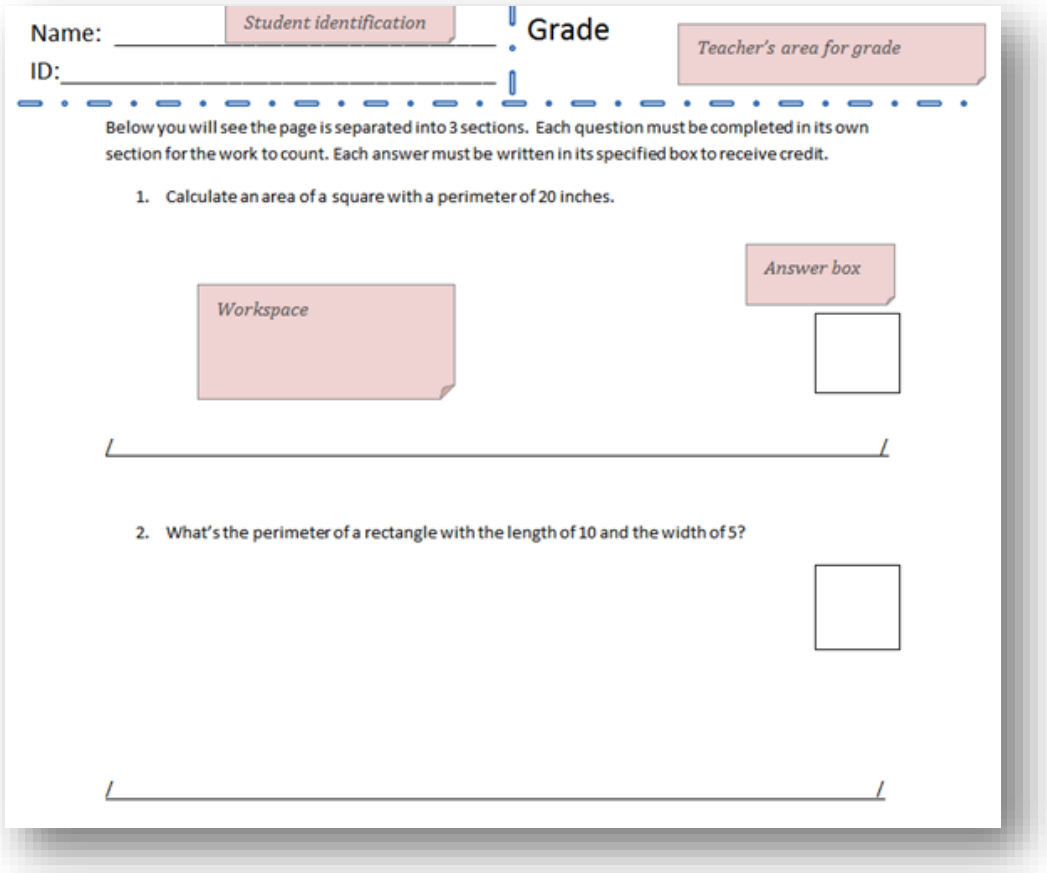


Figure 2. Mockup homework paper

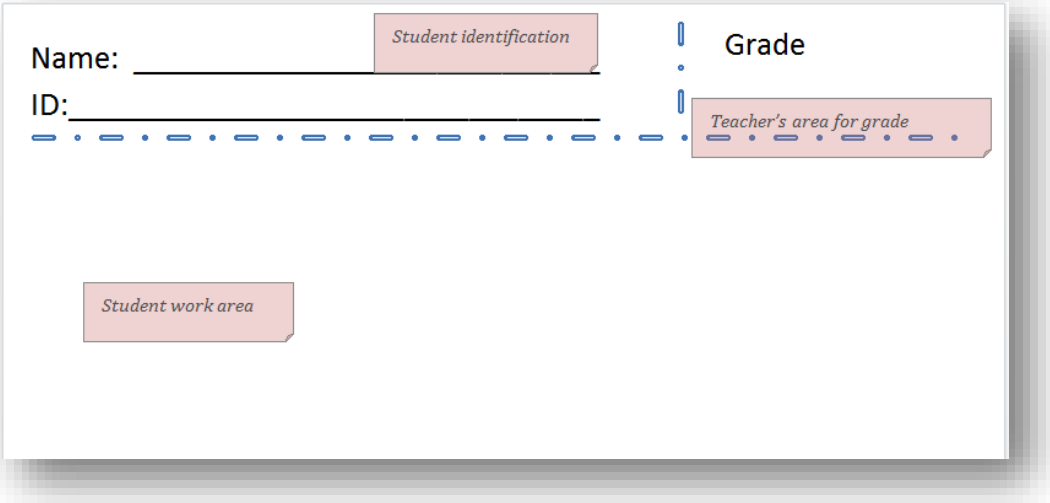


Figure 3. Mockup coversheet

Database

A database is an organized collection of data. In the school environment, teachers could benefit from gathering additional data from students' assignments and exams. Learning standards define what all students in a school should know after passing the class. For instance, when a teacher creates a problem set, he or she can assign learning standards to different questions. Once the problem set is graded, the intelligent scanner could automatically identify correct and incorrect answers. Then, the scanner could compile statistics based on those learning standards.

Figure 4 and Figure 5 show a mockup screen of what information teachers might see if the intelligent scanner system were implemented. Figure 4 illustrates how information might be displayed for individual students. Figure 4 shows individual student performance for multiple subjects in different grades. Figure 5 provides similar information as Figure 4, except it displays the performance of the entire class. This could be useful if the teacher wants to gauge how the class is doing as a whole or simply does not have the time to look at each student individually.

In addition to having more information available for teachers, the database use case could be used to track the students' progress over time. This use case was considered because teachers have very little information regarding their students' mastery of class material from previous years. The lack of information posts difficulties for teachers because they are unable to create an effective teaching plan to help the students with their weaknesses. For example, teachers may have to assume that every student in the class has prior knowledge of

multiplication, even though some students in the class do not. This inhibits those students from learning new material because they have yet to master the basics. We can potentially solve issues like this by creating a universal database for students so that teachers can easily refer to them when assisting students.

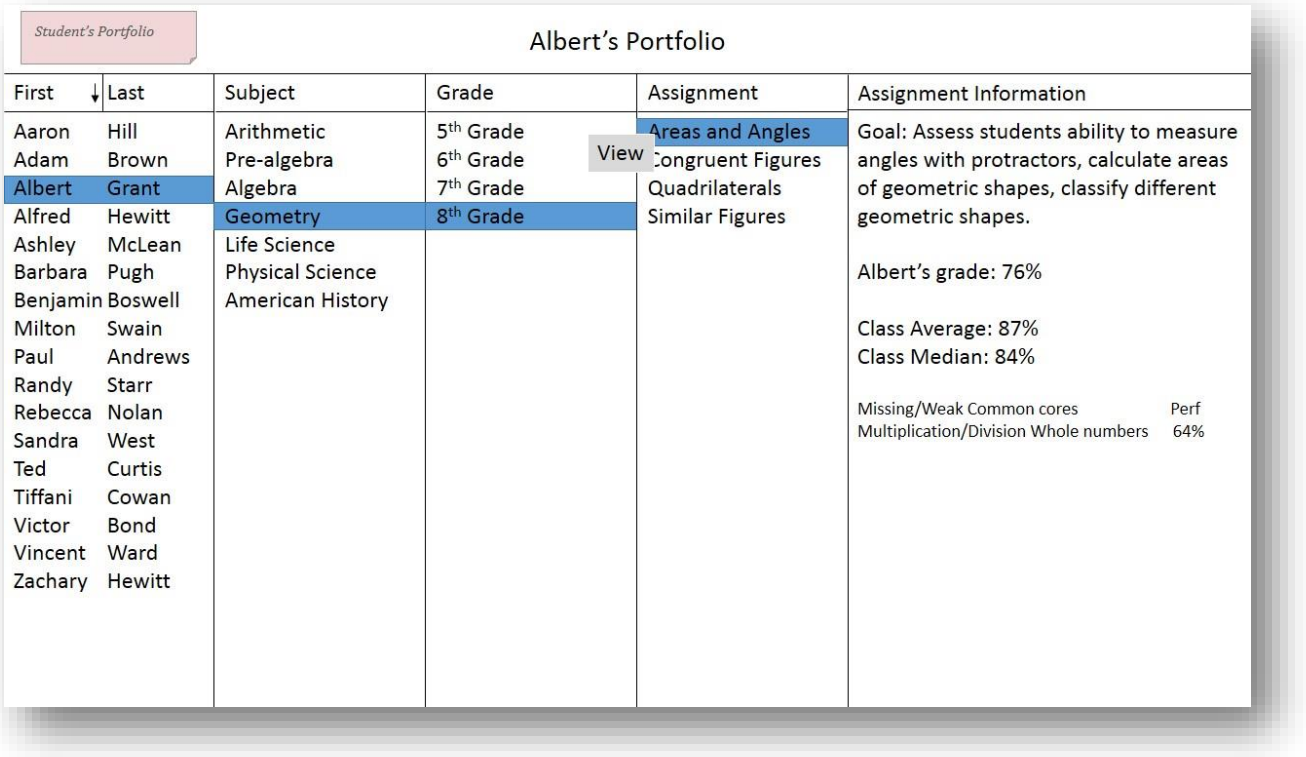


Figure 4. Screen mockup of individual student's database interface

If teachers have to create such a database manually, it would be a lot of work because each student's progress would have to be tracked by hand. If this system were implemented, the database software would increase the teachers' effectiveness, while requiring a minimal increase in workload for the teachers, since the process is automated. As mentioned earlier, we can use the formatted paper to approach this situation.

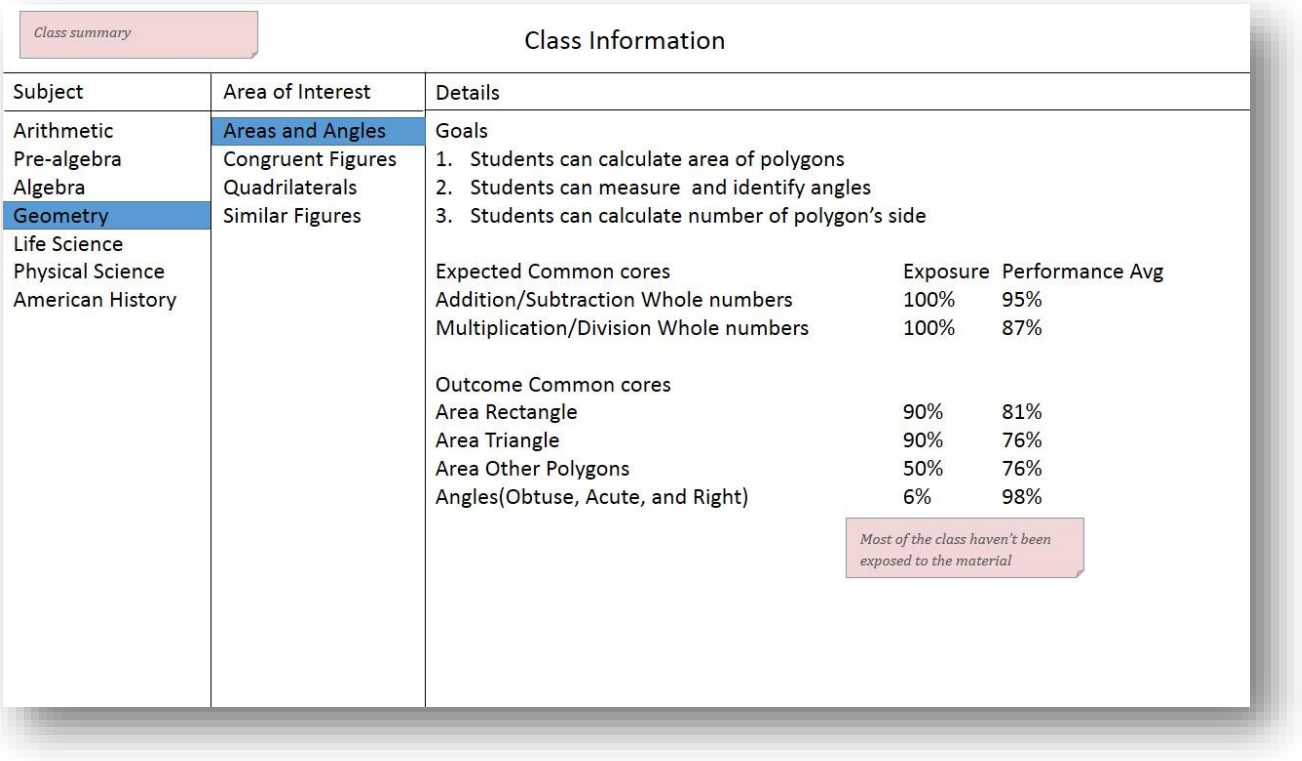


Figure 5. Screen mockup of class information database interface

Automated Grading

The goal of automating the grading process is to reduce the teachers' workload. Ideally, the software would be able to analyze the students' homework assignments and exams and then assign the appropriate grade. This would free up a lot of time for teachers. They would have more free time to accomplish tasks that are more crucial, such as adapting future lesson plans to better accommodate the students.

Computers are not adept at interpreting natural human inputs, so to help aid the software, the formatted paper approach can be used (Figure 2, Figure 3). However, even then, the information may still be too free-formed and nearly impossible for computers to interpret. To simplify the requirements, this system would only be applied to number-related answers,

including addition, multiplication, and physics or chemistry calculations. Even then, it might still be difficult for computers to recognize numbers in different formats, such as proper versus Improper fractions and decimals versus fractions. Thus, teachers may need to implement further restrictions on the students' input of answers.

4. Interviews

First Interview

Our first interview was a great experience for us. We learned a great deal about how the interviewee felt regarding our ideas of an intelligent scanner. We also learned a lot about the interview process as a whole. First, we were able to successfully articulate our ideas to the interviewee as well as receive ideas from the interviewee. Our exchange was somewhat fluid and organic, though this was something that we could work on later to improve. Our ability to direct the course of the interview was acceptable, but at times, the interview went in unexpected directions. These tangents were not necessarily negative, but they were something we were not prepared for, especially when it came to collecting the information in an orderly and timely manner. This links back to a previous point of the interview not being as organic as it could be, delaying further questions and responses. To adapt to this, we decided on a few changes to our approach. We combined our note-taking paper and interview questions paper onto one sheet, thus allowing for a much smoother transition from asking a question to writing down notes regarding the interviewee's response (A1. First Interview Protocol and A2. Second Interview Protocol). We also learned a lot about the way information should be presented to the interviewee, as to not lead or bait the interviewee towards an idea, but to allow them to think openly instead. This was not a huge concern of ours, as our interviewees were intelligent individuals, but any unintended guiding of ideas was to be avoided as much as practical. This concern came about after we presented to our first interviewee the mockups we made for a hypothetical user interface for our data system (

Figure 4, Figure 5). We found that instead of the mock-up helping the interviewee visualize our idea, the mock-up led the interviewee in the direction of our system. The interviewee nonetheless provided insightful thoughts on the system, but we felt that our approach ended up closing the interviewee's thoughts to a less abstract discussion. In future approaches, we decided it best to inform the interviewee more clearly that our mock-up is not actually implemented, but rather a hypothetical design.

Our first interview was a great step for us to learn what an actual middle school teacher would want in an intelligent scanner. Before this point, all we could do was speculate and assume certain things. As long as common sense is used, this works well, but can only go so far. Much of what we assumed a teacher would or would not care about was in fact wrong, as we would learn right away.

The first lesson that we took away from our first interview was that our interviewee did not grade homework assignments. Instead of grading the homework assignments, she instead checked the assignments for completion. If a student attempted the homework, then the student would receive full credit, so being able to automatically grade homework was not that important to our first interviewee. This was a bit of a shock to us, because our previous idea of automatically grading homework assignments was one of our focuses. Another one of our ideas that the interviewee had concerns about was the formatted paper. The issue here was that paper is expensive, especially in her school district, because the teachers have to buy their own. She told us that it would not be reasonable for teachers to provide so much printer paper on their own. Another issue she found with the specially formatted paper was the idea of using

student IDs to help identify each student. She was a little concerned that it would take a long time for the students to remember their identification numbers. She instead suggested that the identification numbers be preprinted on the paper, to ease the process. One final concern that the teacher had was the issue of accuracy. She made it clear that in order for her to want to use automated grading on exams, the accuracy would have to be very high. The accuracy would have to be higher than the theoretical value of 80% that we gave her.

The first interview was also a positive experience, because we learned what the teacher liked about our ideas. She was most interested in the use of a database to be able to record each assignment electronically. The reason for this, as we found out, was due to the new grading system used at her school. Each assignment was not graded by a percentage out of one hundred, but instead by a numerical grade out of four. The fact that there are only five grades a student could receive on any assignment (zero through four) makes it very difficult to justify giving a student a three instead of a four. The interviewee felt that our system of an electronic database would ease this difficulty by allowing the teacher to show why the student got such a grade by having the assignment pulled from the database. She told us this type of system could be used at parent-teacher conferences or at other times when a student's grade may come into question. Another idea of ours that the interviewee liked was for the ability of a teacher to see a student's growth over the year in a given area. Our idea of breaking down each assignment's questions into different areas of subject matter would really help a teacher identify where and why a student was struggling. However, she did warn us that there was not enough time for each student to be examined in this way, but in select cases, it would be very helpful. Furthermore, she was very optimistic about the ability to break down assignments for the class

as a whole, especially on a question-by-question basis. She said this would allow her to see where she went wrong or right in her lessons.

Findings

Likes

1. The ability for teachers to be able to tag questions and to get information will save them valuable time needed to assess students.
2. In a school district where the 4-point grading system is adopted, teachers found it hard to defend their position against parents who are dissatisfied with the students' grades. With this system in place, we will be able to provide teachers data that are more concrete.
3. The information we want to provide teachers with, like a growth model or the ability to provide the common wrong answer, would have to be easily accessible and well presented for it to be useful.
4. If teachers can spend less time on the grading process, they would have more time to teach.

Dislikes and changes

1. The amount of paper needed by the teacher could be an issue in schools that have lower funding.
2. Most assignments that are not exams are not always graded, but are simply just checked whether students completed the assignment or not.

Second Interview

The second interview was also a great success for us. This being the second interview, we were able to fix some of our mistakes that we had made on the previous interview and to pursue our successes. We were once again interviewing a very tech savvy teacher who had a keen interest in the connection between technology and pedagogy. That being said, his responses to our questions were most likely not typical responses that we would expect from an average middle school teacher. This was both to our advantage and to our disadvantage. The advantage was that any question or idea that we presented to the second teacher would be well understood. The interviewee would better understand what angle we were coming from with each question, and if he did not, then we would know for sure that the question was poorly phrased. This was also the chief disadvantage, because the knowledge that this teacher possessed would lead to an uncharacteristic understanding of our subject matter, something the "average" middle school teacher would not have. This meant that we ran the risk of asking a question that the "average" middle school teacher would not understand, but our more tech savvy teacher would. Having foreseen this risk, we tried to work this to our advantage. We had this second teacher look at the rough draft of the survey we made. We asked the teacher to see if there was anything that he did not understand or anything that did not seem clear. We figured that if this more tech savvy teacher could not understand our questions, then a less tech savvy teacher probably would not either. We also used the fact that this teacher was more tech savvy than average by interviewing him as such. Instead of answering our questions superficially, this teacher was able to answer our questions in a very in-depth way, from a tech/pedagogy focus, similar to our first interview. This was extremely helpful, as we expected

later interviews with less tech savvy teachers to be less in-depth on the technological aspects. By interviewing such tech savvy teachers first, we hoped to weed out any questions or concepts that an "average" middle school teacher would have a hard time with, as well as to use the experience and knowledge of these more tech savvy teachers to improve our questions as well as look at new ones. Both of these goals were achieved.

Findings

1. He rates himself a 9 out of 10 on tech savviness and is a teacher of math for 15 years at Millbury Junior High.
2. Paper is not a limiting resource at his school.
3. Surprisingly, a person who rated himself 9 out of 10 on tech savviness has never used a scanner.
4. Grading is the most time-consuming task, and he only grades homework by completion.
5. He spends a minimum of 4 hours a week on correcting work.
    a. Would not assign more work even if he had more time.
6. He believes teachers need to grade students work as a way of communicating.
    a. This helps teachers discover trends for students.
7. Any idea that can replace and make something more efficient without any repercussions is a great idea.

Likes

1. The interviewee accepted the idea of a scanner being able to grade his students work for him, but we again ran into the problem that homework is only graded on completion.
2. He was very intrigued on the idea of quantifying students' performance and achievements in class, because it would help him fill in "the holes."
3. He feels that anything that can help save teachers some time without having any side effects is a good idea.

Dislikes and changes

1. Some good criticism the interviewee gave us started when asked if having a portfolio of student's performance of previous years would be helpful. The teacher agreed that it was a great idea, but the issue of time would restrict teachers from doing this.
2. A teacher does not have the time to go back and reteach previous aspects of math. Like others, he did not like there only being an 80% accuracy on assigning automated grades. To him, it was either 100% correct or he might as well do it himself.

Third interview

Our third interview was much different from the first two interviews we conducted as well as all of our later interviews. We were given an opportunity to interview a large group of middle school teachers from the Worcester area who were currently using the ASSISTments platform. This gave us a unique opportunity to collect information from a group of teachers who use technology in the classroom. This was especially a good opportunity because the teachers had been using ASSISTments, an up-and-coming technology that has been using some very similar ideas to our own, albeit from a different angle.

The main difference between our third interview and all the other interviews was that we did it in a group environment. Instead of interviewing a single teacher one-on-one as we did previously, we interviewed twelve teachers at once. This led to an open discussion instead of an interview. Instead of us asking a question then getting an answer, like with our other interviews, we would ask a question and a discussion would begin. From there, a natural evolution of the discussion would take place, touching upon several different issues. This was very beneficial, in that we were able to hear the views of many different teachers in less time. The down side of an organic discussion was that it was hard to take notes, because many ideas were being discussed at the same time. Instead of writing notes during the discussion, which would have been a ridiculous hindrance, we let the discussion take place and note the general ideas for what the teachers had to say. After the discussion was over, we immediately wrote down everything that was relevant in our time with the teachers.

Another double-edged sword that we found with a group interview was that many ideas were expressed, but they were not as in-depth as the ones from a one-on-one interview. However, we were able to collect a large amount of quality information in a short amount of time, because there were many intelligent and informed teachers in the room at once. Each topic had teachers inputting great ideas. The problem with this was that not all of the teachers were contributing to the discussion. Only about half of the teachers were consistently expressing their points of view. Nevertheless, this was expected to occur in a group environment. Several outspoken individuals gradually led the discussion in a direction more towards their points of view. The quieter individuals did not contribute as much or at all, which led to an uneven discussion. This natural phenomenon resulted in us not getting the opinions of many of the teachers, because they did not bring as much to the discussion. However, this assumed that every teacher was equally interested in giving his or her opinion.

Findings

1. Teachers lack information about incoming students.
    a. They do not know how students performed in previous grades.
2. Students perform differently in different conditions.
    a. Some students perform better with pen and paper, while others are better using ASSISTments.
3. Students' performance information is not available to teachers across different grades.
    a. Teachers have to base their lesson plans on the curriculum, which is much less flexible.

4. Reviewing each student individually takes too much time. The database would most likely be used on a case-by-case basis.

Likes

1. The teachers advocate a hybrid system, where students could choose to use either the paper format or the online format.

Dislikes and changes

1. Not all teachers have used scanners before. A few of them learned how to use one a few days prior to the interview.

Fourth Interview

Our fourth interview went very well for us. It was definitely our smoothest interview we conducted because we had already had a good amount of practice beforehand. In addition, this interview was our last interview with just one interviewee, which also made the process much easier. A third factor that led to the success of the interview was that it was the first interview conducted by all three of us, where before it had always been just two of us. This made it much easier because the tasks of asking questions and taking notes were split between three people instead of two, allowing for less note taking and more effort on conducting a good discussion with the teacher.

We found that this teacher had many good points about some of the issues with our system. One of his biggest concerns was money. This issue was brought up several times by the interviewee, as he taught at a public school with limited resources. He told us that his school had trouble replacing its decade-old printers, so instituting a completely new system, which revolved around scanners, could be an issue. Paper was also a limited resource at his school, further emphasizing the issue of funding. He also brought up a point about partial credit. He was concerned that the system would not be able to assign partial credit for a question answered incorrectly, but that still had the right approach. For example, this would be an issue if a student answered a question incorrectly because of a simple mistake in flipping the sign of a number. He said that a system would have to be able to give a student partial credit in such a situation. He gave a very good suggestion of having the system grade such a problem by having the student give answers to each step of the problem until they reached the final answer. By grading each step, the student would have to prove an understanding of the entire process and

give a correct answer to each step of the process. Both of which are necessary for a correct final answer, but this method would also allow partial credit to be given.

There were also several ideas of ours that he liked. For one, he thought that our system of using a scanner to grade homework was a good idea. He, like all the other teachers that we interviewed, did not grade students' homework assignments, but instead checked for completion. He liked the idea of using the scanners to grade homework assignments, because the scanner could both check for completion and grade the students based on their answers, something not currently possible. Another idea of ours he liked was the use of the scanners to create an electronic portfolio. He liked the idea of being able to see how students did on an assignment as individuals and as a group. This would allow him to see the strengths and weaknesses each student had. He did warn us that this could only be used sparingly, as there was not enough time to teach every student all of the material they failed to learn in previous classes. Instead, he said it would be helpful to see what the class might be lacking as a whole and to do a short review.

Findings

1. He has been teaching math at Worcester East Middle school for 5 years.
2. Funding can be an issue, especially at an older inner city school.
3. Grading of work, specifically exams and quizzes, needs to have partial credit for questions that have multiple steps.
4. Questions should be segmented for easy partial credit assignment.
5. Many schools do not have scanners, so teachers have minimal experience using them.

Likes

1. Interviewee seemed to be fond of the idea of being able to use a scanner to grade homework for completion or for correctness.
2. If teachers were able to see a student's work in electronic form, it could help them identify the student's strengths and weaknesses.
3. It would definitely be beneficial if a teacher could see how a class did on an assignment individually and as a whole.

Dislikes and changes

1. The technology must give a student's work partial credit if the problem is complex.
2. Even though the thought of having a student's work history from previous years sounds like a good idea, time constraints pose a problem.

Fifth Interview

Our fifth and final interview was a double interview with two high school teachers. At this point, we were comfortable with the interview process and were just focused on getting critical feedback from teachers. One interviewee was an information technology teacher at Worcester Technological High School, and the other was a former software engineer now teaching math at Blackstone Valley Regional Vocational Technical High School. Going into the interview, we were hoping to get some good viewpoints from teachers who were not so technically advanced. However, we found this was not going to be the case with one being an information technology teacher and the other a software engineer. Even though these two teachers both rated themselves 9 out of 10 on a tech savvy scale, this just meant the teachers would understand our idea more thoroughly and give us more in-depth and thought-out feedback.

The double interview proved to be a successful way to get information from the teachers. In past solo interviews, some teachers would be afraid to give constructive criticism and seemed to hold back on some of their opinions. However, with a dual interview we observed that the two teachers could converse back and forth after a question was asked. In this way, they were able to agree on a more concrete view of the question. Therefore, they helped each other understand exactly what was being asked of them, which helped us, because they were able to give a wider array of responses.

The two interviewees were not afraid to tell us when they thought an idea was too farfetched and would most likely not be helpful in a classroom environment. This was helpful

because if an information technology teacher or a software engineer teacher did not see the need for our idea, the average teacher probably would not either. The two teachers were still very interested with some of our ideas. They let us know some things about teaching that would help change our ideas for the better. The feedback we received did not add on to our list of already existing ideas, but it clarified which ideas appealed to teachers and which ideas would not be helpful.

Findings

1. The information technology teacher had been teaching for 3 years, while the math teacher had been teaching for 7 years.
2. Paper is a limited resource at these schools.
3. Both teachers have used a scanner before, and there is at least one scanner in their school.
4. Grading is the most time-consuming task for these teachers, which is one of the top reasons why grading should be automated.
5. Most teachers do not give a percentage grade on homework, but a completion grade.
    a. Grading scale of 1-4 on quizzes and exams
6. Teachers believe that they need to be a part of the grading process, because it is a way to interact with their students without having direct contact with them.
    a. They spend anywhere from 2-5 hours a week on grading.
    b. They would not assign more work if given the chance.

Likes

1. The two teachers agreed that grading was the most time-consuming task and would love to speed up the process with automated grading.
2. The teachers liked the idea of quantifying students' work and grades, because it would be easier to keep everything organized and easily accessible.

Dislikes and changes

1. The teachers, along with some previous interviewees, criticize the aspect of grading homework, because they only grade on completion of the assignment. The automated grading of homework would then have to be on a completion scale of 1 to 4.
2. The two interviewees said that if there were a 20% chance of the automated grading being incorrect, that would mean they would still have to go back through the students' work to find the errors and correct them.

5. Interview conclusion

The teachers that were interviewed seemed to be intrigued by the ideas that we formulated. They all seemed to have the attitude that if these ideas were possible, it would save them a significant amount of time, and it would help them focus on the more important aspects of teaching. Some views were clearly more approved of than others were. One of the bigger concerns was whether teachers would have the time to use the resources we wanted to give them. An example would be the portfolio of students' previous records. We overall were very pleased with the feedback our interviewees provided us with, and hope that one day, our ideas can be put to real use to help aid teachers' workloads.

6. Comments and Concerns

Scan time

We conducted a small experiment to see how much time it took for a scanner to scan a sheet of paper. Table 1 shows the results of the experiment.

Model of the scanner	Dot-per-inch (DPI[1])	Duration of scan
Gordon Library scanner	150 DPI	2.5 seconds
WPI computer science department scanner	200 DPI	.82 seconds
Library scanner	300 DPI	4.7 seconds

Table 1 – shows scan time for different scanners and settings

With this information, we came up with theoretical scenarios to estimate how much time per day each teacher would need to use a scanner. Please note that the number of students in each class and the number of classes per teacher are numerical assumptions.

$$T = \frac{t * n * c * p}{60}$$

$T = total\ time\ per\ teacher\ in\ minutes$

$t = time\ to\ scan\ 1\ page\ in\ seconds$

[1]DPI refers dot density on an image. The higher the DPI the longer it takes to scanner because high DPI meant higher resolution thus require more time for

$n = number\ of\ students\ in\ each\ class$

$c = number\ of\ classes\ per\ teacher$

$p = number\ of\ pages\ of\ homework\ per\ student$

Pessimistic Scenario – Long scan time, more students per class, and more classes per teacher

t = 10 seconds, n = 30 students, c = 6 classes, p = 3 pages

90 minutes per teacher

Optimistic Scenario – Shorter scan time, fewer students per class, and fewer classes per teacher

T = 3 seconds, n = 25 students, c = 5 classes, p = 3 pages

12.5 minutes per teacher

Funding

Another point of concern is the issue of money. Every teacher that we talked to brought up the issue of funding in his or her school. Obviously, no school has unlimited resources, but many schools have little to no resources left to spare. In order for a system like the one we proposed to work, schools would have to invest in an appropriate number of scanners for the size of the school, meaning that they would have to spend a considerable amount of money. In addition, many schools, as we have found out, have issues with the availability of printing paper. Most of the schools that the teachers we interviewed worked at had some form of a

limit on the amount of free printing paper they could use. These limits would make implementing a system like ours very difficult, and in some cases, impossible. If every school that tried to implement this technology ran into funding issues, then this project could not reach its full potential.

Since funding is an issue, we could reduce the cost of the intelligent scanner implementation. We could implement the system in a way, such that students could make their own specially formatted papers from notebook papers. This would reduce the strain on the schools' resources. Additionally, we could adopt the distributed scanner model, which would be explained in the future work section. Overall, the scanner is still a feasible idea.

7. Future Work

Integration

This research explored how a standalone scanner technology could help teachers improve their effectiveness in the classrooms. Other technologies could be used in conjunction with this technology, such as ASSISTments, cell phones, and tablets.

ASSISTments[1] is a capable technology, but it is confined to the web environment. This means that students have to have access to computers with internet connection. The scanner technology could extend the reach of ASSISTments. Current students without computers at home are forced to stay late at school or come to school early to do their homework. If scanner technology could be integrated with ASSISTments, those students would be able to do their

[1] ASSISTments - http://www.assistments.org/

homework at home. Teachers could then scan the students' work then upload that work to ASSISTments. This integration allows ASSISTments to be more flexible and to reduce the amount of lab time. This also allows a school to reduce the total number of computers needed per student because of the option of scanning handwritten work.

Cell phones are used to make phone calls less and less every day. Even the "dumbest" phone on the market today has Short Message Service (SMS) or text capability. It is conceivable to have students do their homework by sending answers as short text messages. This would provide real-time feedback to the students. Moreover, the teachers would have an electronic copy of students' answers, which would be more useful for analysis than answers written on paper. Answers as text messages are useful because the majority of current middle school homework is not graded. Instead, students are awarded points based on whether they attempted homework or not. In this way, text messages can be used as well by providing feedback on completion and accuracy.

Distributed scanner model

As stated in the Comments and Concerns section, scanning time could post a problem to a large school with limited resources. Even if teachers have students write answers on a one-page answer sheet, the scan time may still be an issue.

Thinking slightly outside the box led us to think that a distributed model might solve this issue. The imaging technology improves every day. Scanners are not the only tool that can be used to digitize records. Digital cameras have the capability to generate images with high enough resolution for software to perform optical character analysis. Many modern

smartphones are also capable of this kind of functionality. We can harness the wasted potential of these tools and allow them to be used in ways people never thought of.

8. Appendix

A1. First Interview Protocol

Protocol:

- Assessment questions
    - Explain the goals of the questions

i. **The questions are meant for us to assess the needs teachers like you may have and fill them**

    - Ask questions

1. **What is a task that you would most want to be automated in your daily routine?**
2. **Please list some of your time consuming tasks.** (Ideas for more use cases)
3. **Do you know what a PDF scanner is? (explain if no)**
4. **Would you be interested in using scanner technology to help you grade?**
5. **Would you be interested in using scanner technology to help you keep a historical record of a student's' work?**
6. **What about being able to see your students' work on problems the class had difficulty with for homework?**
7. **Is this something you think would help benefit faculty at your school and why?**

- Database
    - Overview of the database

i. **Imagine we have stored all of your students' homework and exams. Everything is categorized by subjects and sorted by dates. You can apply filters to narrow down available information. You can also have an option to visualize student grades based on his/her score and its associated category**

    - show screenshots (Individualize one first then the class)
    - Ask questions

1. **Would it be helpful to have a student's portfolio from current/previous year(s) in an electronic document?**

    a. **What might you do with the data?**

2. **Would it be helpful to quantify students' performance/improvement?** (Similar to Prof. Fisler grading method)

3. **Can you better assist students who might be struggling if you have their past work to look at?** (This include individual assignments, exams, performance in certain areas)

- Automated grade input
    - Overview of the idea
        - **Let say you just finished grading students assignments and instead of manually entering the grade for each student; you can simply put all of those papers on a scanner and the grades would be entered into the system**
    - show formatted paper
    - Ask questions

1. **Would you want to automate grade entering tasks?**

2. **If we can assign grades to students based on your grading with 80% accuracy would you be ok with it?** [MIGHT WANT TO MENTION THAT STUDENTS CAN CHECK]

- Automated grading
    - Describe what this might mean
    - Questions about automated grading

1. **Do you wish you could assign more homework but, because of the grading load, you do not do so?**

2. **How much time per week do you spend on grading student work?**

3. **Is grading students' work something you believe needs to be a part of every teacher's daily routine?**

4. **How do you feel about the idea of automated grading?**

5. **What part of grading homework do you wish could be automated?**

- Free response

A2. Second Interview Protocol

Profiling Questions

1. **How long have you been teaching?**

2. **Where are you currently teaching?**

3. **What subjects do you teach?**

4. **On the scale of 1 to 10 how technically savvy would you describe yourself?**

5. **Is paper a limited resource at your school?**

Protocol:

- Assessment questions
    - Explain the goals of the questions

i. **The questions are meant for us to understand and help address the needs teachers like you may have**

- Ask questions

1. **What is a task that you would most want to be automated in your daily routine?**

2. **Please list some of your time consuming tasks.** (Ideas for more use cases)

3. **Have you ever used a scanner?**

4. **Would you be interested in using scanner technology to help you grade?**

5. **Would you be interested in using scanner technology to help you keep a historical record of a student's' work?**

6. **What about being able to see your students' work on problems the class had difficulty with for homework?**

7. **Is this something you think would help benefit faculty at your school and why?**

- Database

- Overview of the database

i. **Imagine we have stored all of your students' homework and exams. Everything is categorized by subjects and sorted by dates. You can apply filters to narrow down available information. You can also have an option to visualize student grades based on his/her score and its associated category**

  - show screenshots (Individualize one first then the class)
  - Ask questions

1. **Would it be helpful to have a student's portfolio from current/previous year(s) in an electronic document?**

a. What might you do with the data?

2. Would it be helpful to quantify students' performance/improvement? (Similar to Prof. Fisler grading method)

3. <u>Can you better assist students who might be struggling if you have their past work to look at?</u> (This include individual assignments, exams, performance in certain areas)

- Automated grade input
    - Overview of the idea
        - **<u>Let say you just finished grading students assignments and instead of manually entering the grade for each student; you can simply put all of those papers on a scanner and the grades would be entered into the system</u>**
    - show formatted paper
    - Ask questions

1. <u>Would you want to automate grade entering tasks?</u>

2. <u>If we can assign grades to students based on your grading with 80% accuracy would you be ok with it?</u> [MIGHT WANT TO MENTION THAT STUDENTS CAN CHECK]

- Automated grading
    - Describe what this might mean
    - Questions about automated grading

1. **Do you wish you could assign more homework but, because of the grading load, you do not do so?**

2. **How much time per week do you spend on grading student work?**

3. **Is grading students' work something you believe needs to be a part of every teacher's daily routine?**

4. How do you feel about the idea of automated grading?

5. What part of grading homework do you wish could be automated?

Free response. (Notes below)

A3. Online Survey

We did not mention the survey because we did not have a large enough sample size. We only got responses from three teachers.

Intelligent Scanner Survey

Please feel free to omit any questions you may feel uncomfortable answering or irrelevant to you. Project Goal: Figure out how scanners can make teachers' jobs easier by letting technology handles tedious tasks. Survey Goal: Assess needs for this type of technology.

General Questions

How long have you been teaching? In years

- ○ > 30
- ○ 20 - 29
- ○ 10 - 19
- ○ 0 - 9

What subjects do you teach?

- ☐ Mathematics
- ☐ Science
- ☐ English
- ☐ History
- ☐ Other: _____

On the scale of 1 to 7 how technically savvy would you describe yourself?

	1	2	3	4	5	6	7	
Not technically savvy	○	○	○	○	○	○	○	Technically savvy

Is printer paper a limited resource at your school?

○ Yes

○ No

Survey Question

What are some of the tasks that you would most want to be automated in your daily routine? Check all that apply

- ☐ Entering grades into computer
- ☐ Homework grading
- ☐ Looking through students portfolios
- ☐ Come up with test/homework questions
- ☐ Identifying students' needs
- ☐ Problems analysis (ex. 55% of students did this question wrong)
- ☐ Create adaptable lesson plans (ex. Adapting lesson plans based on class performance)
- ☐ Other: _____

Do you wish you could assign more homework but, because of the grading load, do not do so?

Don't wish to assign more work — Wish to assign more work

How much time per week do you spend grading student work? Amount of time in hours

- ○ > 40
- ○ 30 - 40
- ○ 20 - 29
- ○ 10 - 19
- ○ 1 - 9

Would you prefer a machine to grade students' work, or would you prefer to grade it yourself? How about a mix of the two? Please explain.

Would it be helpful to have students' portfolios throughout the years in an electronic form? Portfolios would include past homework, tests and other relevant work

	1	2	3	4	5	6	7	
Not helpful	○	○	○	○	○	○	○	Very helpful

How might it be helpful or unhelpful? How might you use it?

Would you like to be able to easily see student's prior homework and exams in mathematics? Ex. Student's strengths and weaknesses

○ Yes

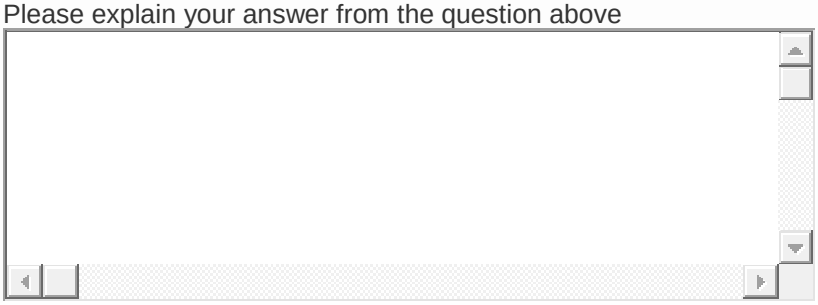
○ No

Please explain your answer from the question above

Would it be acceptable to have students' complete work on specially formatted papers? Similar to scantron, formatted paper would have students write their names and answers in specified areas.

- Yes
- No

Please explain your answer from the question above



Technical Background

How comfortable are you with using scanners/learning a new software?

	1	2	3	4	5	6	7	
Not Comfortable								Very Comfortable

Have you ever used a scanner?

- Yes
- No

If the technology existed, what would it do to make your job easier? Please use your imagination :)

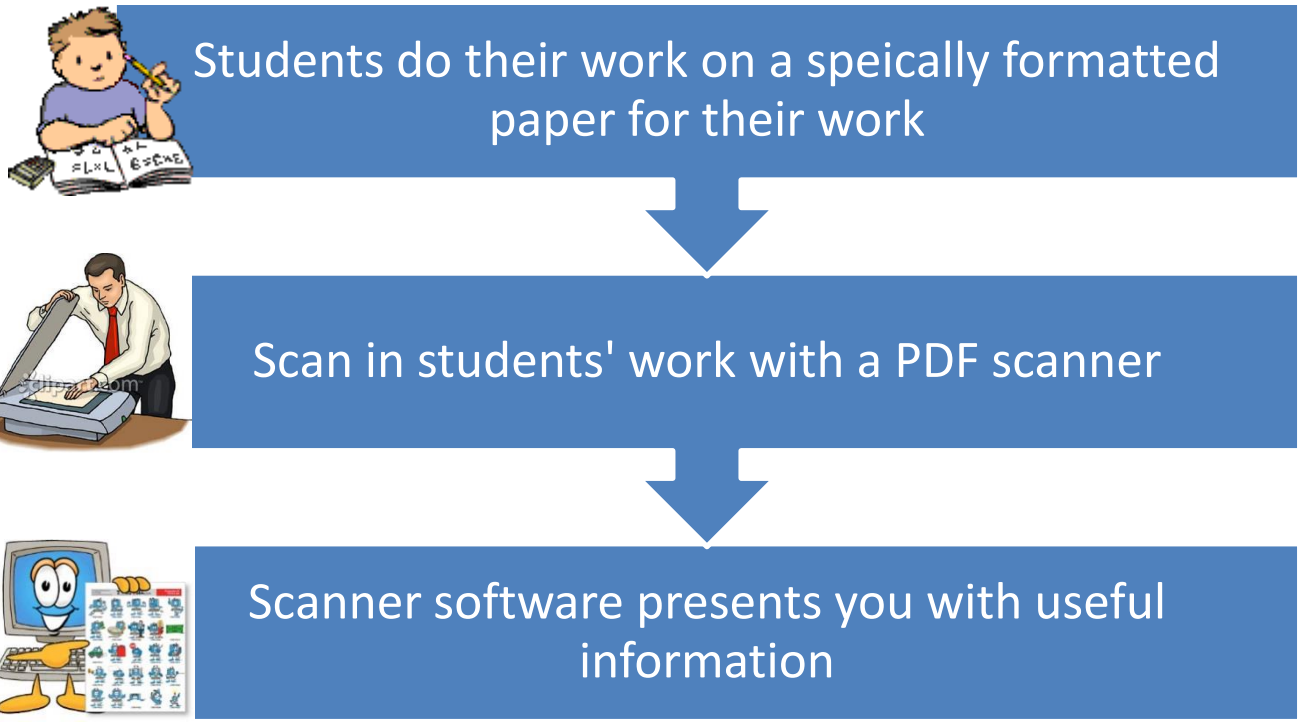
Submit

A4. Interview Handout

Intelligent Scanner Project

Project Goal:

In todays' world, teachers are occupied with too much grunt work such as grading daily homework and entering grades. These menial tasks distract teachers from their true profession, teaching. The purpose of this project is to conduct a needs analysis for a tool to reduce the menial tasks for teachers, more specifically in a middle school environment.



Please feel free to contact us if you have any questions, concerns or **additional ideas** by emailing intelscanner@wpi.edu

A5. Existing Open Source Projects

Currently, there are a couple of open source projects that future research groups could use to build the software needed for the scanner.

- http://www.codeproject.com/Articles/74348/Handwriting-Recognition-using-Kernel-Discriminant
- http://www.codeproject.com/Articles/16650/Neural-Network-for-Recognition-of-Handwritten-Digi

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