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Shortening Remediation Time in a University Excel Course through Custom, Automated Feedback

Kainalu Barino

Design & Development Project

Brigham Young University

Project Purpose

This project aimed to implement an automated feedback tool for students taking IS 110. Implementing a feedback tool was identified by a previous research group as one of the best ways to shorten remediation time (Colby, 2018, p. 1). They chose a design for their feedback tool that resulted in faster turn-around times and better scores on assignments, but their design did not improve test results by a significant margin. Our project redesigned the feedback tool in the hope that it not only maintains the benefits of the previous tool, but achieves long term learning results as well.

Background Information

The current IS 110 team consists of the client, who is an instructor and subject matter expert, my supervisor, and myself as the tool designer (referred to as the IP&T team). The original tool designers were two graduate students. Before the original team started work on the project, MyEducator at the time only provided answer-based feedback. Answer-based feedback happens after the student inputs an answer for all the questions and then submits their assignment. The platform then grades the assignment and tells the student which problems they got wrong and their overall score on the assignment. Feedback given this way is unhelpful because the feedback is provided after the fact and, as the previous team described it, "[MyEducator] does not provide enough information for a student to diagnose what is incorrect about their answer" (Colby, 2018, p. 2).

The original team went on to design the Step-based Feedback tool (SBF) to enhance MyEducator's default tool. How the SBF tool works is that it triggers immediately when a

student gives an incorrect answer; the tool announces that the student's attempt was wrong and gives one of three hints. These hints are leveled hints, the first hint being a general hint and instead, a more detailed hint following a second and third incorrect attempt. Eventually, the SBF tool told the student exactly what was wrong with their answer, which the original team called a "bottom-out hint".

The SBF tool designed and implemented by the original team yielded positive results (Colby & Staples, 2018). They saw a significant increase in assignment scores between the class using the SBF tool and the class that only had access to MyEducator's default answer-based feedback. However, differences in midterm scores between the two classes were not significant, implying the SBF tool provided short-term gains but lacked long-term benefits. Unfortunately, the original team did not pursue a version of their tool that would make up for this lack in improved test scores. Our goal with our new Reverse Q-matrix (RQM) feedback tool design was to improve long-term results while maintaining the benefits achieved by the original team.

Project Needs and Constraints

Online learning has been an emerging medium in higher education. One obvious advantage of online learning over meeting in-person is the capability to enroll more students because students can attend classes at a distance rather than reserve seats in a physical classroom. Moreover, asynchronous online classes allow students to move at their own pace. Brigham Young University (BYU) decided that its Information Systems 110: Spreadsheet Skills and Business Analysis class, or IS 110, should be offered as an asynchronous online course, making

adapting the materials and curriculum a primary concern for the instructors. One of the biggest issues the instructors faced was providing adequate support for the higher enrollment count.

The class size limit for the online IS 110 class is set at 550 students. Instructors and TAs have expressed that even at half the limit, it is still difficult to assist students in a timely and meaningful manner, at least without sacrificing responsibilities in other areas of their jobs. As a result, instructors have seen students languish in completing assignments, as evidenced by the data logs pulled from their online platform MyEducator. The data logs show students spending long periods of time completing problems instructors thought were easy. Instructors have reasoned that implementing a tool through MyEducator that gives feedback immediately would provide the reach and the just-in-time help the students need to succeed.

Learner Personas

This section profiles a typical user of our product and discusses whether or not the unique characteristics of our users merit any special consideration. The product is essentially a homework aid for students enrolled in the introductory online Microsoft Excel business class (IS 110) taught at Brigham Young University (BYU). BYU is a private university owned by The Church of Jesus Christ of Latter-Day Saints and primarily enrolls students of the same faith. This section expands each of these factors and explains the impact each has on the design of the product and its implementation.

BYU is a private university whose population is made primarily of college-age members of the Church of Jesus Christ. All BYU students. Faculty, and staff must abide by a Dress and Grooming standard and Honor Code. BYU is competitive in their admissions process. Displayed

on BYU's website is the average GPA of accepted students, which is 3.86, and the average ACT score of accepted students is 28.8, which is higher than the national average ACT score of 21. Looking at the class, IS 110 is an early requirement for many of the business-related majors, including Business Management, Accounting, and Finance. The class has no prerequisite and can be taken any semester. Thus, students taking the class will most likely be recent high school graduates interested in business as a major.

The following are the four primary learner personas that benefit more from our project. All personas were identified by the data logs pulled from the MyEducator Platform for the class. There are many learner personas involved that we chose to exclude, for example students with indicators that show they understand the material well. These students tend to score high on first attempts and complete assignments in less than an hour. These personas tend not to ask or need help because they're comfortable with their scores.

Name	**Challenges**
Lucy (the Lost)	Spends one or more hours completing homework but settles on a final score below 90%.
Rachel (the Reader)	Spends one or more hours completing homework after settling on a final score above 90%.
Quint (the Quick)	Spends less than an hour on homework but has a final score below 90% and doesn't make more than one attempt.
George (the Guesser)	Scores less than 70% on first attempts and makes more than one attempt.

The goal of our feedback tool is to reduce remediation time while improving scores. Lucy benefits from a feedback tool because after a wrong attempt, the feedback tool gives direction on

her specific mistake, preventing her from having to search through different resources to find an answer. Rachel benefits in the same way Lucy does, where the specific feedback results in a successful second attempt and an improved homework time. Similarly, Quint benefits because the feedback tool immediately notifies him of his incorrect answer and gives him the opportunity to then try again with more information. Lastly, George benefits by being given more information to help improve his second attempt and the opportunity to learn from his mistakes. Each of these personas is assumed to be between the ages of 18 and 24, the typical age for a college student.

In thinking about these personas, the SBF tool design would not benefit George because a guesser would get the question wrong until the bottom-out hint is displayed, then George would input the correct answer and move on, not learning much. This reinforces bad habits while our new tool provides feedback based on the incorrect answer. By having feedback change according to the student's answer, the student is forced to correct their specific mistake since our feedback tool doesn’t reveal what is the correct answer.

Environmental Analysis

Our client is also an instructor and represents other business professors that teach the IS 110 Excel class. He originally taught it traditionally, as an in-person synchronous class, but has since switched to the online textbook provider MyEducator, which students access via purchasing a subscription. Now, he and his TAs supervise the hundreds of students doing their assignments remotely each semester. The class is delivered asynchronously – there is no meeting time and students are expected to complete the assignments on their own by reading the book

and/or watching the videos embedded in the digital textbook. The size for IS 110 has grown considerably since the change to online, which has made it hard for our faculty representative and his team to reach and identify students who need help.

IS 110 is currently hosted on MyEducator, a platform known for its interactive textbooks and mobile access. The class is completely paperless; assignments, quizzes, and exams are provided online and completed digitally through the platform. Students therefore need a computer and internet connection. The platform also integrates with Microsoft Excel. Students download an Excel spreadsheet from the platform that has additional features enabled that connect the student to an LMS and other tools. It is through this special toolbar that we implement our feedback tool.

The RQM tool will be programmed in Visual Basic for Applications (VBA). Students will have to allow the script to run on their own Microsoft Excel programs in order to receive the feedback. This is done easily by clicking “Enable Content” when MS Excel prompts the user for permission. VBA is similar to BASIC and is the best option for generating quality feedback, versus typing Excel formulas, which is limited to prebuilt MS Excel functions. The RQM tool will also have to be primed by the IS 110 team before it can be fully implemented. The team will need to look at all the incorrect solutions given by students, identify the gap, and write appropriate feedback. The feedback will then be stored and called by the RQM tool whenever a student submits a similar incorrect answer.

After installation, the RQM tool runs in the background ready to alert the user when it has feedback. In this regard, the product is non-disruptive, has no learning curve, and essentially acts more as a feature of Excel; students simply choose to open the message or not. Messages

containing feedback about incorrect solutions will automatically popup to the right of the cell containing their answer. Once the RQM tool is primed and installed, no further maintenance is needed by the instructors. On each assignment, students will be reminded how to access the feedback, so they do not forget this help exists. Any complaints about the feedback tool can be immediately handled by our team.

Task Analysis

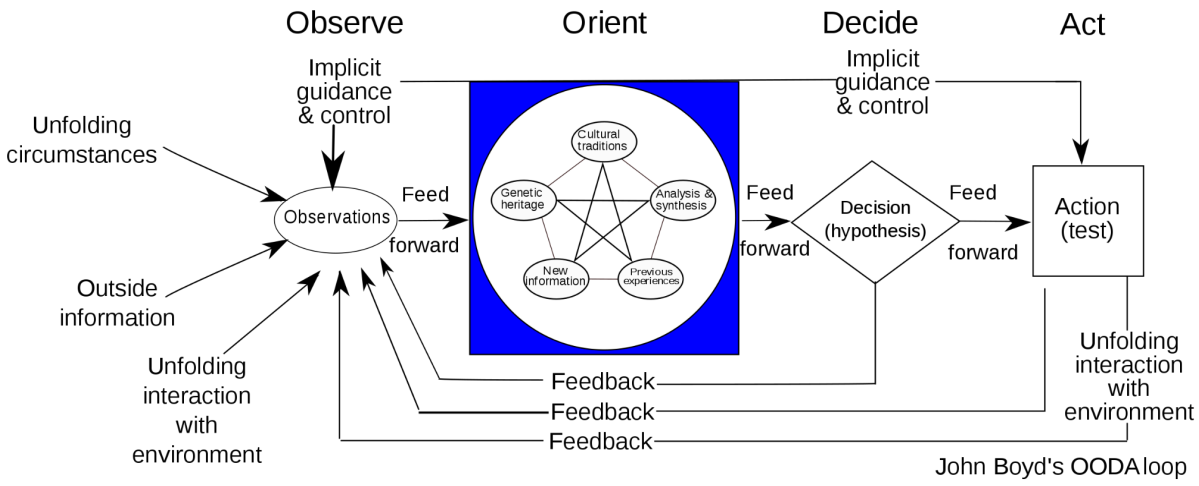
Since the IS 110 class aims only to expose students to the basics of Microsoft Excel, the primary task for students is learning *how* to learn effectively, and our product assists students with this endeavor. Our project goals are to shorten the remediation gap and improve test scores. Successful students use their resources effectively, such as the reading materials and videos, complete their homework assignments quickly and with accuracy, and internalize the concepts being taught. All students get problems wrong on their initial try, but successful students will know where to find the answers they need and quickly fix their mistakes. Successful students also have a strategy for situations in which they get homework problems wrong. These students quickly take the necessary steps to fix their mistakes and close their learning gaps.

The Boyd Cycle (or OODA Loop), created by U.S. Air Force Colonel John Boyd and illustrated in Figure 1, outlines the process of forming and executing an expert planning for learning. Students that struggle to correct their mistakes struggle at the Orientation stage of this model. These students may lack previous experience, the skill to analyze and synthesize a good solution, information about the problem, and so on, or a combination of these factors, to be able to help them make a good decision about how to proceed with the homework assignment. Our

product intervenes at this stage, providing the guidance they need to understand their mistake, correct their mistake, and continue on.

Figure 1

The Boyd Cycle



(Provided by Patrick Edwin Moran under Creative Commons Attribution 3.0)

When students are able to correct their understanding at the Orientation stage of the Boyd Cycle with our RQM tool, then we will see the remediation gap close, and we hope to also see improvements to long-term learning, which we plan to measure using test scores. Successful students already take charge of their learning and move through the Boyd Cycle expertly.

Product Design

Design Details

The concept of a reverse Q-matrix is what powers our tool. A reverse Q-matrix (RQM) is similar to a Q-matrix but instead of pairing problems to learning outcomes, it pairs incorrect answers to possible knowledge gaps. When an incorrect answer is submitted, the RQM tool determines what knowledge gap the mistake represents, then provides feedback specific to that gap. For example, if the correct answer is "=SUM(A1:A2)" but the student submits "SUM(A1:A2)", the RQM tool will know that this mistake is something minor and will provide a kind of reminder feedback, e.g., "You forgot the equal sign to start your formula." If a student submits "=COUNT(A1:A2)", this mistake represents a larger knowledge gap and the RQM tool will respond accordingly, with different, better-suited feedback.

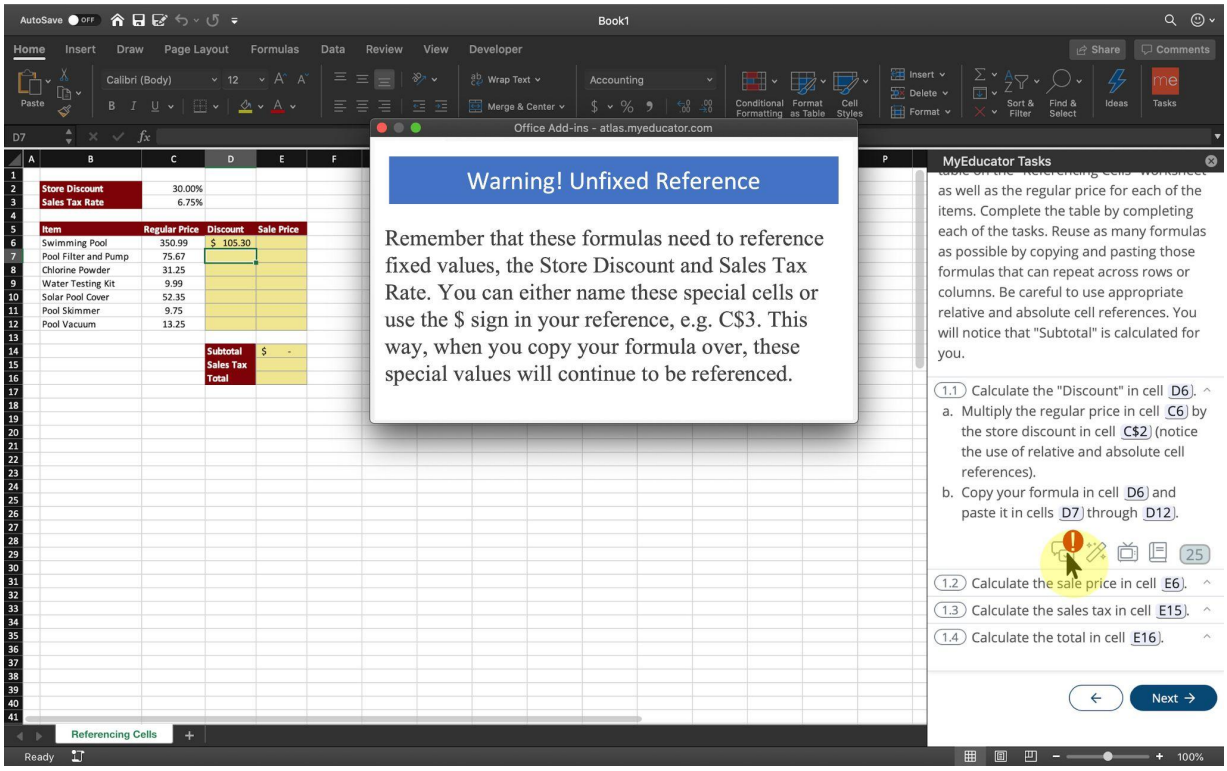
In the background, the platform MyEducator has been recording student responses for each homework question. Through these data logs, we can compile a list of each incorrect submission, look over them, and determine what knowledge gap the incorrect submission represents. Then, specific feedback is written by the instructor and stored, students making the same mistake will receive the same feedback. This process is how we created the table used by the RQM tool. The delivery of the feedback is automatic and we wanted to keep the feedback loop tight by having the tool display the feedback immediately after an incorrect submission. Our project has two goals, to provide students with timely guidance, measured by improved times spent on homework, and to improve learning, as measured by test scores. Timely feedback was proven by the previous research team to improve homework remediation time and so, nothing

has changed with our iteration. Through precise, actionable feedback, we hope to improve the long-term learning that happens.

The entire tool is implemented and contained within Excel, which provides a few advantages, among them, the ability to make quick fixes should the need arise. The content for the feedback is stored on a separate sheet within the assignment and can be readily adjusted by the IP&T team, and even consulted by the students. Being able to edit feedback is important because if the feedback actually decreases or complicates student achievement, the feedback content can be quickly edited. Having the tool be developed internally improves maintenance - changes to the feedback can be done by team members with a little programming experience through Excel itself and the tool does not require upkeep required by third-party tools.

Figure 2

Feedback Popup First Design

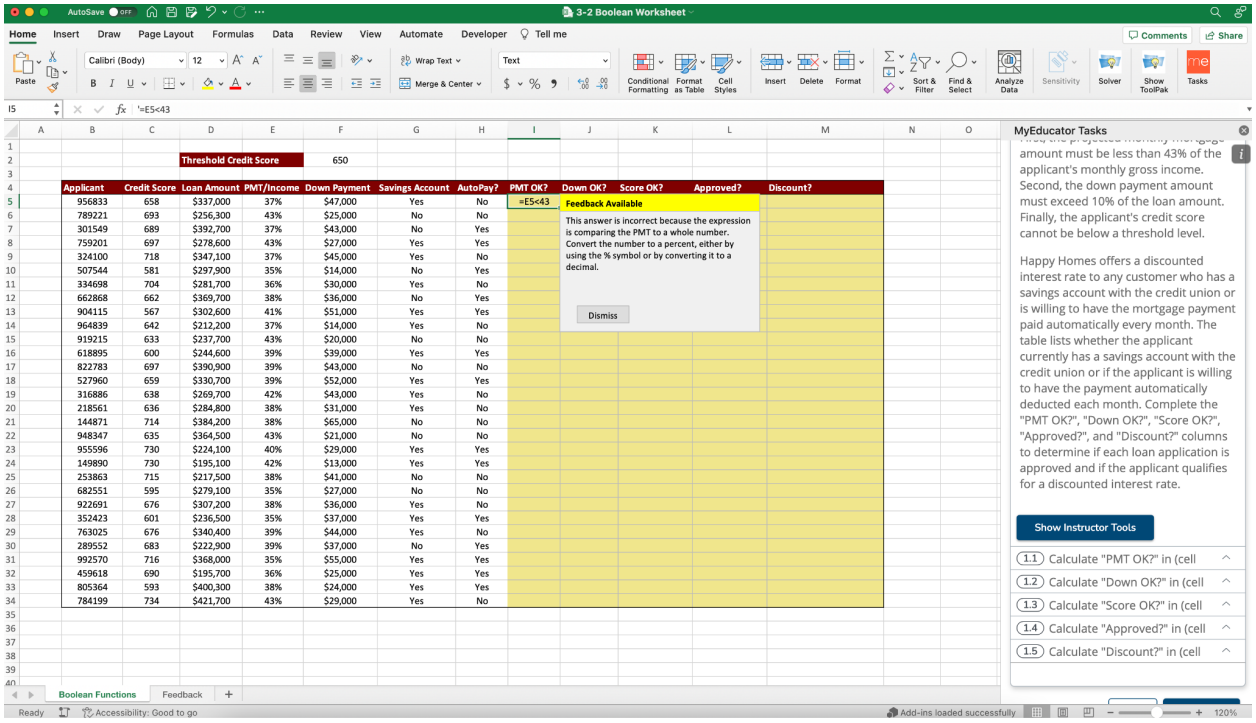


Note: The computer cursor at the bottom right hovers over the feedback tool on the toolbar. When a mistake is made, a notification icon pops up. When the user clicks on the tool, feedback related to the exact error is given to the user.

Originally, the feedback popup acted as a full modal, taking over the screen (Figure 2), but we've since changed it to appear next to the active cell, which is less intrusive (Figure 3). The toolbar also has a red notification icon that appears when the student makes a mistake, just another way to notify the student. The new design of the popup is simple, with a dismiss button and a yellow header.

Figure 3

Feedback Popup Second Design

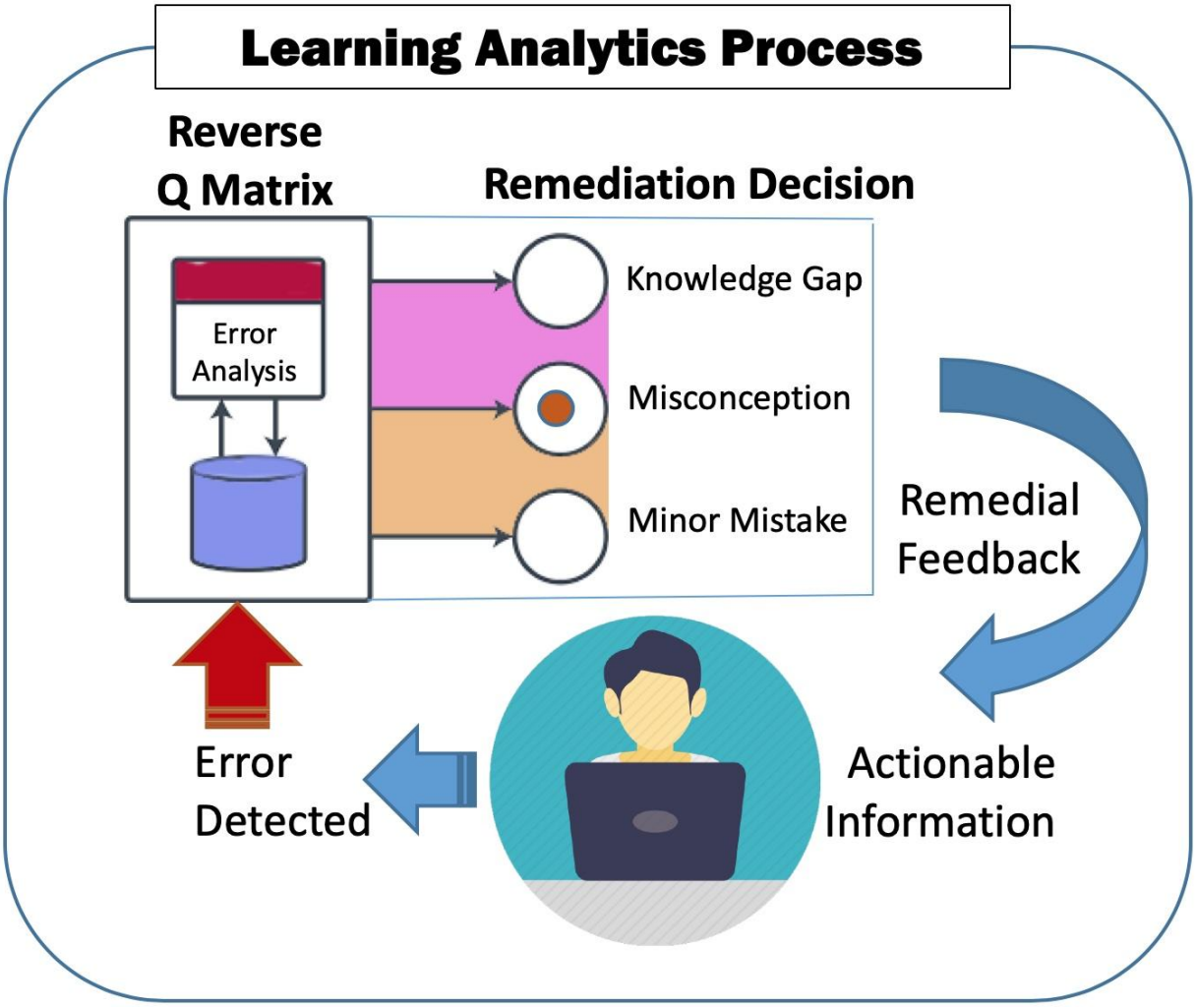


Note: The feedback popup is less intrusive in this iteration.

Figure 4 details the learning analytics process of a reverse Q-matrix. Each error is classified as a minor mistake, a misconception, or a larger knowledge gap. Feedback for each kind of mistake might be longer or shorter depending on the severity.

Figure 4

Learning Analytics Process



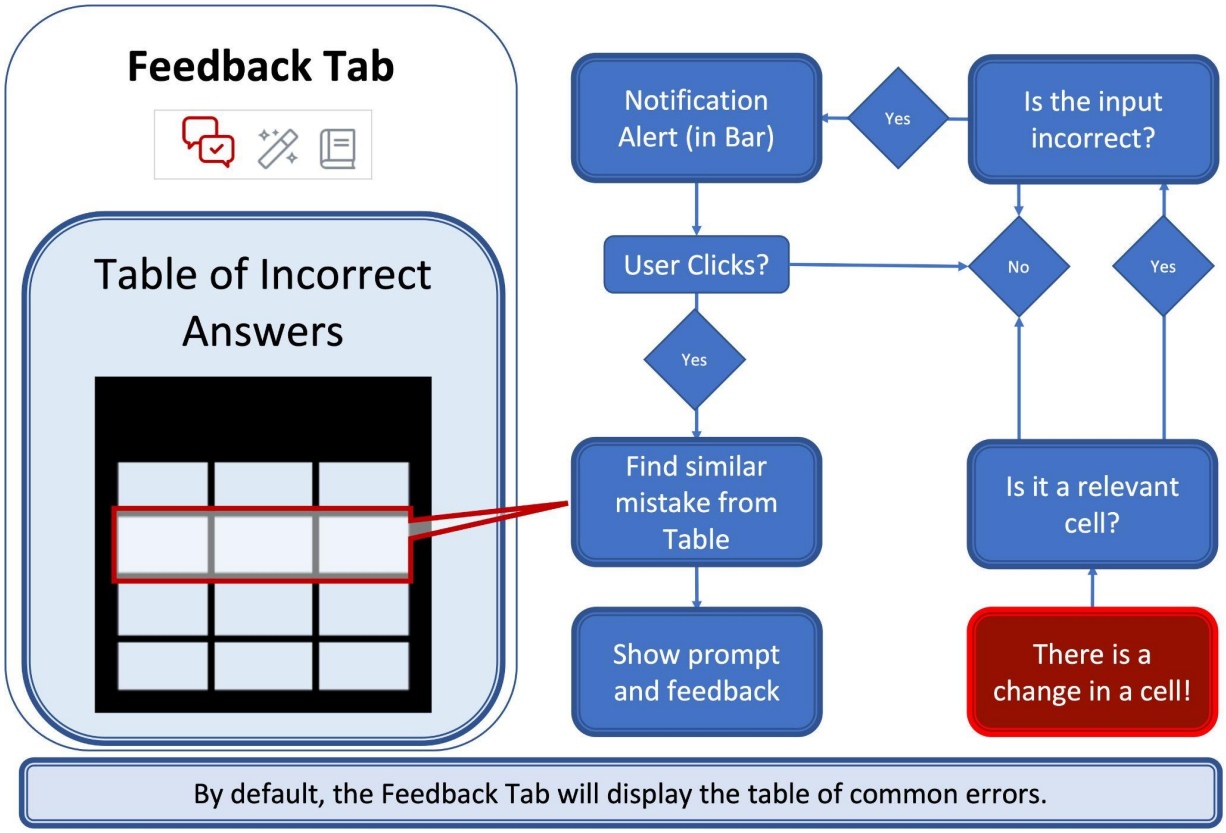
Note: This diagram outlines the design of our feedback tool.

The logic for our tool follows the flowchart below (Figure 5). This behavior is what is coded in VBS. The tool waits for a change in any Excel cell. If the cell is relevant, then it checks to see if the input is a correct answer or not. If the input is not correct, then it looks for the

mistake that matches the input on our table of errors and finally displays the associated feedback. The student now has the option to dismiss the feedback and try again or to continue.

Figure 5

Tool Flowchart



Note: The flowchart starts when the tool detects a change in a cell and illustrates the logic.

Table 1 shows a sample of the data collected from the MyEducator platform. The platform gathered data in the background and we used that data to compile a list of the common mistakes students were making. For example, the first two rows show correct answers while row

three has the first incorrect submission. In this case, students forgot to represent the value as a percent and typed 43 rather than 0.43 or 43% (or similar).

Table 1

Sample List of Top Errors

#	Correctness	Student Input	Frequency
1	Correct	=E12<0.43	30546
2	Correct	=E12<43%	13258
3	Incorrect	=E12<43	1002
4	Correct	=(E12<0.43)	459
5	Correct	=(E12<43%)	419
6	Correct	=AND(E12<43%)	383
7	Correct	=$E12<43%	324
8	Incorrect	=E12<=43%	256
9	Correct	=IF(E12<43%,TRUE,FALSE)	243
10	Correct	=AND(E12<0.43)	239
11	Correct	=$E12<0.43	193
12	Correct	=IF(E12<0.43,TRUE,FALSE)	189
13	Incorrect	=E12<=43	142
14	Correct	=IF(E12<43%,TRUE)	118
15	Incorrect	=E12=43%	111
16	Incorrect	=E12<=0.43	70

Note: The top five incorrect responses from students are displayed in rows 3, 8, 13, 15, and 16. This data was retrieved from MyEducator.

Once we identified the most common mistakes students were making, we used it to write feedback telling the student simply why their answer is wrong and how they can fix it. This table is stored on a separate sheet within the assignment. Table 2 shows a sample of that table.

Table 2

Sample List of Feedback

Incorrect Input	Feedback
=E5<43	This answer is incorrect because the expression is comparing the PMT to a whole number. Convert the number to a percent, either by using the % symbol or by converting it to a decimal.
=E5<=43%	This answer is incorrect because the inequality needs to be strictly less than the PMT. Change the inequality from <= to <.
=E5<=43	This answer is incorrect because 1) the inequality needs to be strictly less than the PMT; use < and not <=, and 2) because the expression is comparing the PMT/Income to a whole number. Convert the number to a percent by either using the % symbol or by converting it to a decimal.
=E5=43%	This answer is incorrect because the expression checks for equality and not to see if the PMT is less than the given percentage. Change the = sign to <.
=E5<=0.43	This answer is incorrect because the inequality needs to be strictly less than the PMT. Change the inequality from <= to <.

Note: For each common mistake, we wrote simple feedback the tool references. Feedback content needs to be easy to understand and actionable.

The tool has been created for only a few assignments. We tested the tool with a few students for proof of concept. Depending on the success of the product, we will proceed to analyze each assignment and create a table of errors.

Design Process and Evolution

The IP&T research team decided that improving automated feedback was the best way to overcome the population problem and decrease the time spent on easy problems. If technology can be programmed to respond to incorrect answer submissions with appropriate guidance, students would not have to hound instructors for feedback or wait in line to do it, as has been

traditionally observed. In fact, Orrell (2006) found that students complain that they are not given timely feedback on their work, and instructors complain that students do not heed the feedback when given, creating a persistent feedback issue. The question remains, however, of what kind of feedback should be given and how should the feedback be delivered.

Providing feedback has positive effects on student learning (Hattie, 2008; Poulos & Mahony 2008). Feedback generated by the system can be as minimal as an indication that the answer is correct or incorrect, but studies show that more detailed feedback can lead students to correcting mistakes more often than when they receive minimal or no feedback; this improves the learning experience and effectiveness overall (McKendree, 1990). Feedback is the most efficacious immediately following incorrect responses (Smith, 1988). Mutch (2003) points out that, "If [feedback] is to be effective, it needs to be a part of the developmental process and, further, one that is reinforced laterally during a student's studies" (p. 19). Within higher education, the literature shows that feedback that includes information about how to improve performance and does not compare the performance of the recipient with that of others are particularly beneficial (Evans, 2013).

Following the guidance provided by the research, the RQM feedback tool will not wait until the entire assignment is submitted but respond to submissions for each individual problem, as either congratulatory for correct responses or hints for incorrect responses. The feedback hints will provide direction but not reveal the solution, and of course, feedback will avoid punishing language that shames the student. Hints will be customized based on the incorrect answer, meaning there could be several kinds of hints to a single problem. This help will thus be more practical than generic feedback hints.

Among those tasked with improving the automated feedback were two IP&T graduate students. Both designed and implemented the SBF tool in the course and have seen positive results. Though the improved feedback tool produced significantly higher scores on homework assignments than on assignments completed without the feedback tool, tests show that midterm scores were not significantly different. This is just one of the reasons why the IP&T design team is revisiting the feedback tool seeking to make further improvements.

One of the improvements would be changing the way the computer decides what kind of feedback to give. SBF is an improvement over flag feedback, feedback that only indicates a right or wrong answer. However, not only has SBF been shown to have an insignificant impact on midterm scores, but students may be skipping directly to the bottom-out hint to move forward, a fear that the original team admit with their SBF tool but were unable to test. The IP&T team wants to change the current SBF tool that utilizes a reverse Q-matrix. Two different ideas for how the RQM tool would deliver feedback were considered by the design team: Early Warning Feedback and I-Do-You-Do Delivery.

Early Warning Systems are systems used by schools that capture critical student data and use it to identify students likely to drop out. Early Warning Feedback would work in a similar fashion, but instead of alerting administrators, it would alert the student to their potential of failing an exam in the hope the student goes back and studies to increase their chances of success. This system utilizes a predictive model that takes into account homework scores for individual assignments, number of attempts, total time spent on each problem, and other factors to predict that student's exam or quiz score (statistically, this is done with linear regression). Together with the prediction would be suggestions on what the student should study in order to

increase their predicted score. This method of providing feedback is possible to implement with only a few adjustments to the RQM tool but the lack of research on this topic makes it a risky choice to consider.

In an I-Do-You-Do Delivery system, feedback would not be provided on every problem. Instead, feedback would be provided on one problem and the student would be left to do a similar problem on their own, like how a teacher might help a student on the first problem but then ask the student to try the second problem on their own. Anecdotal evidence suggests that this kind of feedback system discourages students from depending entirely on the feedback hints to complete the assignment, but further research must be done about this kind feedback loop and would be an interesting question for future research.

Product Proof of Concept

Usability Testing

Once designs were completed and the tool developed with our VBA logic and feedback table, we tested the user experience by conducting usability testing for five users, as per the Rule of 5, which is a qualitative sampling of user experiences, usually an initial testing group of five members, in the development phase of a product to identify the majority of issues. Faculty found that students struggled most with Unit 2 and Unit 3 of the Excel class, and so we chose a section in Unit 2 to install our tool. The section was about Boolean Logic in Excel. In order to get a representative sample, each user had to be at least familiar with Microsoft Excel and some experience with how functions work. We also chose users who were current college students.

These students would receive a quick explanation about the interface, then they would start on the assignment. The following questions helped us select users for our testing.

1. How many years of experience do you have with Microsoft Excel or other spreadsheet programs (e.g., Google Sheets)?
2. On a scale of 1 to 10, a 1 being completely new, and 10 being an expert, how would you rate your familiarity with Microsoft Excel?
3. On a scale of 1 to 10, again, 1 being completely new, and 10 being an expert, how would you rate your familiarity with Boolean functions in Excel?

Once we chose users, we conducted a think-aloud; we gave users instructions to pretend they were starting on an assignment for a college Excel class. Users were asked to complete the assignment we prepared, which had five questions, and to narrate what they were thinking. After the users completed the assignment, we asked them the following questions.

1. (If the user answered all questions correctly) Let's pretend for a moment you got this question wrong. Notice that there is a popup with some feedback. Now please complete the question.
2. (The user encounters our feedback) Do you believe the feedback provided helped you complete the task? Would you want feedback like this to always appear when you get questions wrong?

If the user correctly answered each question, we would have them go back to one of the questions and pretend that they made a mistake and encountered our feedback. Then we asked them the second set of questions.

Testing Summary

Our users had generally positive sentiments. Each user said they would want the RQM tool on every assignment and there was no sentiment made by our users that was negative. Among the sentiments collected, two students expressed that the tool helped clarify acceptable answers to the assignment question. In other words, they misinterpreted what the question was asking them to do but the feedback helped them get back on track. One student said, “Once [the feedback] popped up I instantly knew I forgot to do an absolute reference. I honestly didn’t read it all, like the second I got to the part about the dollar sign I was like, oh, I forgot this.” In this case, just being told immediately that their answer was wrong was enough for the student to pause and quickly realize their mistake.

User comments about the interface design and interaction were also positive, with one student saying, “I liked how it popped up right next to the cell so I knew what it was talking about and then the instructions were clear enough.” Also, as part of our testing, one student entered an answer that was similar to another incorrect answer, and so the feedback did not trigger (they used 43/100 to express 0.43). In this case, I had them input the latter so the feedback popup would display, then had them continue. This highlights one weakness of doing feedback for specific inputs, which we hope to remedy in a final version.

Evaluation

At our tool’s current stage, the main success indicator is a positive user experience. After conducting the usability and user experience test, and if we can confirm proof of concept, we can

move confidently to the next stage of our product, which is building the tool for an entire unit. Then, we can use the homework scores, homework times, and the data from exams to analyze statistical significance and measure success for our original project goals. Since our users had a positive experience with our tool as confirmed by their sentiments, our team will start analyzing the common mistakes for each problem on each assignment and implement the new RQM tool design for the rest of the unit.

Evidence

The IS 110 faculty representative expressed a desire to improve the feedback tool and the original IP&T design team developed the SBF tool. However, the faculty representative expressed that the progressive hints system would be too expensive and time consuming to implement, requiring three hints for each problem. Our tool reduces the amount of feedback by just focusing on the common mistakes and on the specific errors, with one feedback response per item. The feedback would point to the mistakes and provide steps on how to correct those mistakes, which is different than simply providing the correct answer. Students still need to have some knowledge in order to fix their mistakes and would not be given a “bottom-out” option. Allen showed more enthusiasm for this design and we want to implement the RQM tool on more than just one assignment.

Procedures

Our usability test was moderated and had a think-aloud component with the user, where we asked the user to describe what they were doing. Through this process we were able to identify possible pain points but found sentiments to be overwhelmingly positive for both the

design and the feedback content. Five of the five students want the tool implemented on every assignment and found the feedback helpful, with a few surprising results, including one student who said just the act of being told they were wrong helped guide them to a correct answer, and not necessarily the content of the feedback. The usability testing validates the tool's need from the students' perspective but whether or not the tool succeeds at improving learning is something that must be tested differently. The next stage of testing involves quantitative techniques and data from homework scores, time taken to complete the assignments, and test scores.

Outcomes

The design team's main indicator for success on this project is that the RQM tool significantly reduces the time students spend on assignments and significantly increases quiz scores. Other effects our team plans to measure are whether there is a significant improvement in homework scores between students using the SBF tool and students using the RQM tool, whether remediation time was significantly reduced, and whether students find the feedback helpful overall. Student satisfaction with the RQM tool will be measured using a survey that asks students to rate the feedback tool's helpfulness and then provide any other general comments. Comments will be analyzed using generic qualitative methods (i.e., finding common themes among comments). Other tests of significance will be analyzed using appropriate statistical tests.

Currently, the team has collected qualitative evidence of the effectiveness of our feedback tool. The results of this usability test show positive sentiments about the overall design and the usefulness of having the feedback. Users expressed their desire to have the tool implemented on all future assignments, even going as far as to say that there is no case in their mind to not have

the tool. The next stage of our project is to develop the feedback tool for the remaining assignments, implement the tool, gather the data, and see whether our tool reduced time spent on the assignment, improved the assignment score, and improved test scores significantly.

Annotated Bibliography

Our project looks at the feedback issues for BYU online's Microsoft Excel course, taught through the business department. We looked at the overall issues with feedback for online courses in higher education, the kind of feedback that is most effective, and how feedback should be presented. Smith's (1988) work validates that feedback given immediately after the mistake is most effective, and paired with McKendree's (1990) work on the different methods of delivering feedback, helped us develop a basic design for our own delivery logic, while we decided on the reverse Q-matrix model of selecting the feedback content. Poulos and Mahony (2008) helped guide the syntax and word choice of our feedback, remarking that feedback must be actionable to be effective. Overall, it is unquestionable that any kind of feedback improves learning, be it small hints, delayed feedback, or simple flag feedback.

Evans, C. (2013). ***Making Sense of Assessment Feedback in Higher Education,*** ***83*****(1), 70-120. doi: 10.3102/0034654312474350**

This article is a bigger article that does several things, 1) literature review on feedback in higher education, 2) looks at the gaps in the literature on feedback in higher education, 3) discusses the current feedback gaps in higher education, and 4) discusses future directions for research in this

area. This was a great article that brings readers up-to-date on the current issues with feedback in higher education. The literature review also covers international studies. The paper goes on to propose 12 methods for effective feedback and organizes a neat table with each method's main literature backing the method. At the end, provides a strong direction for further research in feedback based on the previous discussion of the themes and issues.

Overall, this is a great source on learning about the general issues with feedback in higher education. The paper lacks consideration for the problem in the context of online classes. The paper does provide many sources on specific issues, letting us sort through which issues are specific to our project's objective.

Hattie, J. (2008). ***Visible learning: A synthesis of over 800 meta-analyses relating to achievement*****. New York: Routledge.**

The book analyzes a lot of the research on achievement, but more importantly for our research, some of it has to do with feedback. Of course we only read the importance of feedback in education. This is great for a general summary of the benefits of feedback in education, a good primer for anyone getting involved with work on feedback.

McKendree, J. (1990). ***Effective Feedback Content for Tutoring Complex Skills, 5*****(4), 381-413. Retrieved from https://dl.acm.org/citation.cfm?id=1455755**

This article talks about "computer-based tutoring systems," and features a study in using the tutoring system Geometry Tutor in teaching high schoolers Geometric proof concepts. The study tries different methods of providing feedback to high school students, 1) minimal feedback, 2) conditional feedback, 3) goal-oriented feedback, and 4) a mixture of both conditional and goal-oriented feedback. The study finds that there is a significant difference between learning outcomes for each of those methods. More specifically, that goal-oriented feedback and feedback composed of a mix of methods were the most beneficial.

Overall, this study had positive results for using feedback, showing that different kinds of feedback does have an effect on learning. The unfortunate downside is that this was successful for high schoolers taking Geometry, a very limited scope. We want to be able to form a theory that speaks to online higher education learning. This supports part of our argument that shows using intelligent tutoring systems has potential for learning in general. This study cannot fully speak to our feedback however.

Mutch, A. (2003). Exploring the Practice of Feedback to Students. ***Active Learning in Higher Education, 4(1)*****, 24-38. Retrieved from http://dx.doi.org/10.1177/1469787403004001003**

Provides a good literature review on assessment feedback. The research looks at certain aspects of giving feedback, including positive comments and negative comments on essays written by students in a higher education business class, and looks at the effect of those kinds of comments on learning. Comments were also categorized into understanding of question, structuring and

argument, concepts, knowledge, communication, and presentation, and the effects of these kinds of feedback were recorded. The author stresses that students also need to be prepared for feedback, giving implied developmental feedback as an example as a good feedback practice but requires some student preparation.

This is not necessarily a study but a look into common feedback practices in grading essays. The author criticizes certain practices but concludes that feedback is important for students and gives several points of advice, including saying, "If [feedback] is to be effective, it needs to be a part of the developmental process and, further, one that is reinforced laterally during a student's studies" (p. 19). Mutch points out other best practices and points to several studies involving the different kinds of feedback. This study might be good to cite at the beginning of my paper as evidence that this kind of feedback is important for student development.

Orrell, J. (2006). Feedback on learning achievement: rhetoric and reality. *Teaching in Higher Education, 11*, 441–456. doi:10.1080/13562510600874235

Observational study on the feedback gap, where students complain that they are not given timely useful feedback on their work, and instructors complain that students do not heed the feedback when given. The study looks at all the stakeholders of student learning, criticizing students and instructors, and even administrators for not building feedback into the learning environment. The study has three main parts: 1) observation of feedback practices, 2) beliefs about feedback for students and teachers, and 3) comparison of feedback behavior and beliefs. The study finds that

there are systemic problems hindering quality feedback in higher education. Partially, instructors felt more inclined to give summative assessments rather than formative assessments on student work, in the form of midterms and quiz grades to pressure students into doing better, which in turn makes students care more about grades than actual learning. In this study, 15 professors were interviewed (n = 15).

The study concludes by outlining an institution's responsibility for providing more formative feedback. This is a good qualitative study about the general issue of feedback in higher education and the shortcomings of professors in timely grading and feedback practices. It suggests students are the product of the system, which does not support (entirely) good feedback practices. This article will be good to cite at the beginning of my paper, making a case for using technology to assist professors in providing feedback.

Poulos, A. & Mahony, M. J. (2008). ***Effectiveness of feedback: the students' perspective, 33(2),*** **143-154. https://doi.org/10.1080/02602930601127869**

A qualitative study that focuses on the student's perception of feedback. Researchers interviewed groups of students varying in grade, completing degrees in Health Science from the University of Sydney. In the interviews, researchers prompted students for their definition of feedback, how they use it, and their preference of the delivery of that feedback. Three main themes emerged from the interviews, and those themes are perception of feedback, impact of feedback, and credibility of feedback. The researchers found that students preferred actionable feedback, feedback that described what changes needed to be done for improvement, and that timeliness

wasn’t necessarily a big issue with feedback. The study shows the codes used and highlights some comments on the issue.

This is a good article that gives a clear direction on the kind of feedback that is expected from students. The article gives great insight into our major stakeholders. It is students that use this product so it is wise to consider students' views on the matter. I will use this source as evidence of the importance of the content of feedback.

Smith, P. L. (1988). Toward a Taxonomy of Feedback: Content and Scheduling, *10th Annual Proceedings of Selected Research Paper Presentations at the 1988 Annual Convention of the Association for Educational Communications and Technology* (pp. 731-746). New Orleans, LA.

Smith writes about the best time to provide feedback (directly after a mistake) and the kind of feedback. Smith finds positive results when feedback follows mistakes than when feedback is delayed. Smith also finds that though congratulatory feedback is nice, students learn the most when making mistakes and benefit more when feedback is detailed. Several ideas about feedback are also discussed in the literature but seeing that this is an older article, we did not explore the references further. Smith was one of the few articles on the importance of the timing of feedback.

Design Knowledge and Critique

Feedback is an essential part of the learning process and the time after a student makes a mistake is a critical time where serious learning can happen. Digital feedback tools improve an

instructor's reach and can be leveraged to great effect. MyEducator does not guide students throughout the entire learning process, at least as outlined by the popular process of I-do-you-do-we-do; MyEducator has the materials to introduce students to the concept (I-do) and provides practice problems (you-do), but this is where the teaching ends and the students are left to teach themselves what they may not have understood. This is where our feedback tool takes over to help the students complete the learning process (we-do) and provides that crucial guidance when students make mistakes.

The previous IP&T team tested a design that was moderately successful in accomplishing its learning goals. The RQM tool is an improvement over the SBF tool in terms of developing the feedback, risk of abuse, and addressing specific learning needs. Some of these improvements were identified after the development of the SBF tool, which motivated the research of using a reverse Q-matrix as the foundation for the feedback tool instead of the leveled feedback approach employed by the SBF tool.

Further improvements to the RQM tool itself may rely on computer AI (artificial intelligence). The team could use the data collected from MyEducator to train an AI system to recognize future mistakes that are fundamentally similar and then provide similar feedback. This would not only make the tool more robust, but cut down on the time it takes to analyze and create feedback content. For example, the following inputs are all technically equivalent but are unique inputs to a computer: 0.43, .43, 43/100, (0.43), and 43%. AI would be trained to recognize that these inputs are equivalent and would then provide the same feedback to help guide the student to the correct answer rather than the IP&T team going through answers and grouping them.

Conclusion

Overall, the project was a success in terms of helping us settle on a design to eventually further develop and test. Our project goals extend to developing the tool for every assignment within a unit so we can conduct tests with a larger class size and see if our tool managed to reduce the time spent on assignments and improve test scores at the end of the unit. At the current stage, we only managed to conduct a usability test for proof of concept and gather feedback from our users. This feedback was positive, with sentiments suggesting that the tool was very useful and that the tool did contribute to the student's success. Now, we can move confidently to the next stages of our project and gather quantitative data.