Development and Implementation of Rapid Feedback Using a Cloud-Based Assessment Tool

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***Abstract*—To design assessments that enable rapid feedback and simultaneously empower instructors to formulate and manage problems, a new cloud-based assessment tool was developed. The online-tool combines the utility of Google Forms and the versatility of developing complex multiple choice problems within Google Sheets. Using this tool, instructors are able to generate a question library, edit numerical parameters that update formulated responses, select assessment questions, and administer the assessments using student smartphones. Students receive their scores instantaneously and are able to review incorrect responses alongside the solutions. A core mechanical engineering course, that previously used paper-based quizzes, was selected for implementation. Apart from automated grading, the use of such an assessment tool provided useful statistics on student performance and quantified key misconceptions. Surveyed students praised the instantaneous feedback and a notably high student engagement was observed following the quizzes compared to when the traditional quizzes were returned. This approach prompts self-evaluation exactly when the students are most receptive to the explanations. The outcomes hint at the next generation of assessment tools for individualized and rapid feedback to benefit student learning.**

Keywords*—rapid feedback; smartphones; online assessment; mobile; quiz; Google Forms; Google Sheets; Google Script

I. INTRODUCTION

Studies show that the use of rapid feedback following assessments within classrooms can directly enhance the outcome of student achievement [1-5]. Implementing rapid feedback has shown great promise in furthering student learning [5], retention [6, 7], and engagement [3, 8-11]. Among these, Opitz, *et. al* [1] concluded that rapid feedback in the form of a Classroom Response System (CRS) "is an effective way to improve interactivity in the classroom". Incorporating rapid feedback in classrooms "reveals misconceptions and improves [student] exam preparation" [3]. Furthermore, studies reinforce that delayed feedback after assessments negatively affect these parameters [12, 13]. Traditional feedback methods such as student-instructor meetings and feedback provided within quizzes and tests, struggle to provide instantaneous feedback to students. The period elapsed between the assessment and evaluation feedback, is time sensitive. The greater the feedback delay, the less of an impact the feedback carries. Students that receive feedback instantaneously after an assessment retain greater material than students who receive feedback significantly later [4]. Methods that minimize the feedback period have the potential to innovate current assessment methods.

Most rapid feedback tools rely on multiple choice questions because these are more conducive to automated grading. The *Fundamentals of Engineering* examination and concept inventories [14] also use multiple choice questions for this reason. Furthermore, multiple choice questions are effective for use in engineering assessments because students are able to easily interpret cause and effect relationships, charts and graphs, and discriminate between fact and opinion [14]. Multiple choice questions are also ideal for comparative studies because they avoid open-ended solutions that can introduce subjectivity [15]. Recognizing these advantages, most rapid feedback solutions prefer instructors develop multiple choice problems. Engineering assessments, and other STEM fields, often utilize complex mathematical formulae based on theory, and therefore effective multiple choice questions need to be systematically developed with common misconceptions in mind. Therefore, for STEM fields, rapid feedback methods must, in addition to providing automated grading, allow instructors to embed problem formulation to simplify assessment generation.

Existing tools, such as Socrative [16], Google Forms [17], Google Classrooms [18], Quick Key [19], Zip Grade [20], Poll Everywhere [21], and others, are innovative solutions that encourage rapid feedback, however they fall short on facilitating a formulated assessment generation. To highlight the importance of embedded formulation, let us consider Google Forms. Google Forms is an intuitive cloud-based platform that allows users to create multiple choice assessment problems. Students can use their smartphones to respond and immediately receive their scores. However, the problems are manually entered within Google Forms and remain static. Instructors must maintain a separate source document where the problem is mathematically formulated using the problem parameters to compute alternative responses. Often, instructors simply recalculate the numeric responses with common misconceptions while preparing the assessment. Having a record of these misconceptions and being able to quickly and easily edit them for future assessments can greatly benefit assessment development. Similar challenges plague most other rapid feedback platforms.

This work attempts to develop a rapid feedback assessment platform that integrates problem formulation crucial within STEM fields. The solution provides several additional benefits that are discussed in this paper. This assessment tool was

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implemented within a core Mechanical Engineering course at Rowan University, namely *Thermal-Fluid Science*, to conduct a pilot study and gain usability insights. This paper discusses the developmental efforts and the outcomes of this implementation. The approach presented here is a critical first step towards a comprehensive rapid feedback assessment platform.

II. DESCRIPTION OF TECHNOLOGY

A. Design Philosophy

Early in the development phase, a cloud-based tool was envisioned to augment existing assessment tools. Later, this new platform was titled *Quipid* for its focus on developing quizzes that provide rapid feedback. Quipid was designed to create technically complex multiple-choice quizzes and provide instantaneous feedback to students. After reviewing existing feedback methods, specific design requirements were drafted for Quipid. These requirements included the ability to select specific problems to be included, update alternatives without recalculation, track common misconceptions, and provide timely meaningful feedback to students. Quipid was designed to offer multiple choice question types exclusively to facilitate automated grading. Additionally, problems can involve images either within the question stem or as alternatives to provide a richer medium for more involved questions.

Considering a multiple choice problem consists of a question stem, figure and alternatives, a dynamic array that grouped individual problem data was developed to generate assessments. Therefore, the alternatives included an answer to the question stem and three distractors. Figure 1 provides an example of such a grouping using the Pythagorean theorem for one problem.

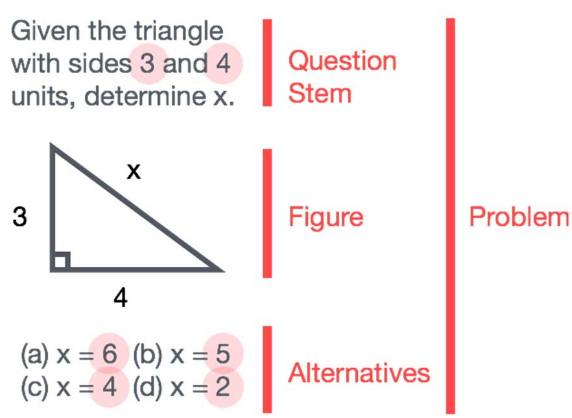


Figure 1. A Problem consists of a Question Stem, Figure and Alternatives. Within the Alternatives, there are three distractors and an answer.

Note that the answer and the distractors in Fig. 1 pertain to the parameters provided within the question stem, i.e. the two side dimensions of the triangle. To edit the problem, instructors traditionally recalculate all the alternatives and update the problem. Instead, Quipid was designed to embed mathematical formulation within the problems, to allow professors to dynamically link parameters and alternatives (as highlighted in red in Fig. 1). In other words, changing the problem parameters automatically updates the answer and the distractors since they are mathematically computed using theory and its related misconceptions.

Considering the versatility of Google products, Google Sheets and Google Forms, were selected as the user front-ends. These user front-ends were mapped using a custom developed algorithm scripted using an object-oriented language similar to JavaScript, called Google App Script.

B. Algorithm

The primary purpose of the algorithm was to automate Google Form generation from existing problems. Once the problems were finalized within Google Sheets, the algorithm would use selected problems to populate a Google Forms document. The assessment can then be administered with minimal processing on the Google Forms document. Figure 2 provides a flowchart of the automated process involving conditional operators. The algorithm only processes problems that have been selected within the Google Sheets for the assessment. Question type is determined based on the alternatives and presence of figure details. The algorithm also allows users to prepare a preamble to the assessment, namely student details, and instructions. Additionally, the algorithm allows every problem to be assigned as 'required' within Google Forms to ensure students respond to every question.

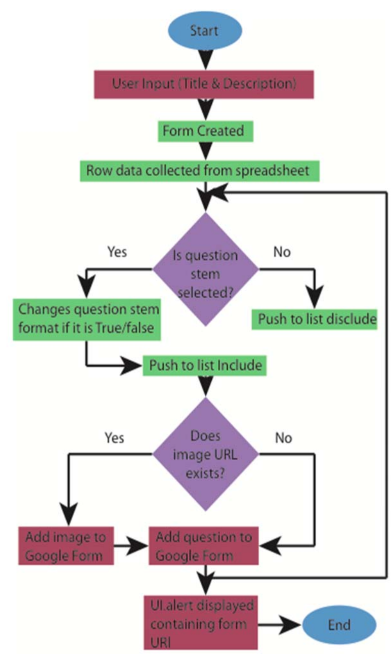


Figure 2. A logic oriented flowchart of Quipid's algorithm highlighting conditional operators.

C. Problem Creation Google Sheets

The process of problem creation begins within a Google Sheets file containing a Problem Sheet and a Formulation Sheet. Figure 3 provides a sample of these sheets using a heat transfer problem to demonstrate the creation process. The Problem Sheet lists all the problems within a library (only a single problem displayed within Fig. 3). Instructors are able to select individual questions for specific assessments. Each problem is referenced to a Formulation Sheet that supplies the question parameters and the alternatives. As seen in Fig. 3, the Formulation Sheet includes various other parameters that are part of the theoretical framework of the problem. The alternatives are mathematically linked using formulae to arrive at the answers based on correct theory and distractors using common misconceptions. Manipulating any of the parameters within the Formulation Sheet updates the alternatives, without additional recalculation. Additionally, since the Problem Sheet uses the Google Sheet "concatenate" function to generate the question stems and the alternative, any edits to the Formulation Sheet automatically updates the Problem Sheet, and thus the problem statement.

Problem Sheet

Stem	Answer	Distractor 1	Distractor 2	Distractor 3
If the exposed surface area is 12 m^2, the thermal resistance of the composite wall is	0.0010	0.0021	0.0120	0.0002

(a)

Formulation Sheet

Parameters	Answer	Distractor 1	Distractor 2	Distractor 3
A [m²]	12	12	1	12
T_1 [°C]	550	550	550	550
k_A [W/m.K]	200	200	200	200
L_A [m]	0.01	0.01	0.01	0.01
T_2 [°C]	500	500	500	500
k_B [W/m.K]	50	50	50	50
L_B [m]	0.6	0.6	0.6	0.6
T_3 [°C]	200	200	200	200
R_{TH} [K/W]	0.0010	0.0021	0.0120	0.0002

(b)

Figure 3. Google Sheets document containing the (a) Problem Sheet linked to the (b) Formulation Sheet for each problem. Problem parameters and alternatives are populated using Formulation Sheet values.

D. *Assessment Generation from Google Sheets to Google Forms*

Once the problems have been refined and 'selected' for the assessment. The embedded Google Script prompts the user to "Generate Assessment." The Google Script adds a menu item within the Google Sheets to activate a sidebar where instructors can add preamble details such as an honor code description and an assessment title. Once finalized, the script produces a Google Forms sheet populated with the preamble details and the problems. Figure 4 provides an example of the Google Forms output for a single representative problem.

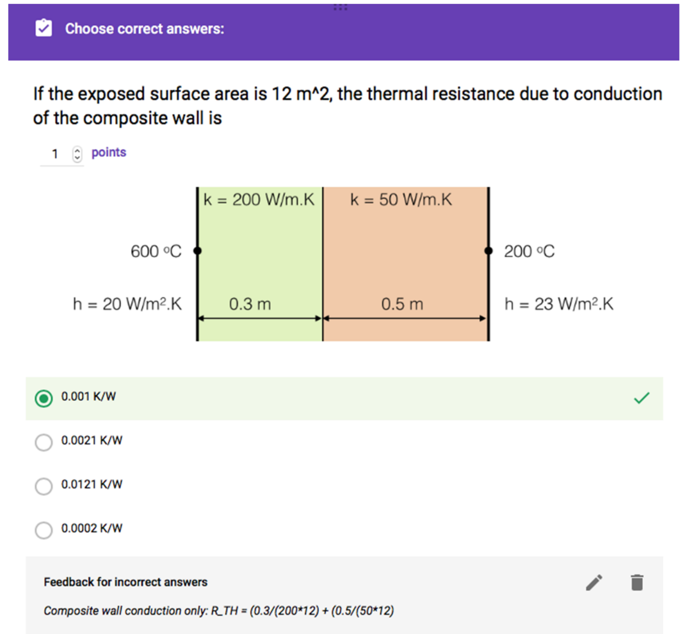
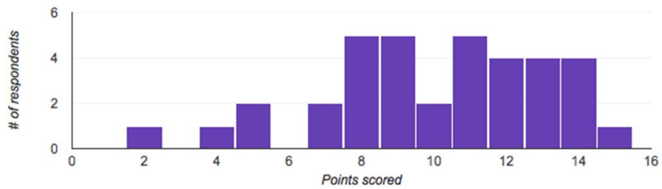


Figure 4. Sample output of a Google Forms problem generated using the Quipid algorithm. Point values are assigned, the correct alternative is assigned, alternatives randomized and feedback provided post assessment generation.

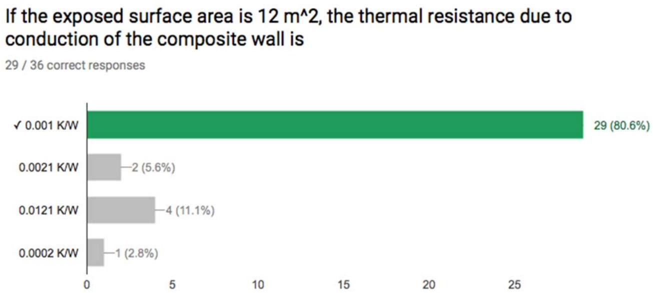
Ideally, the script would generate a Google Forms document ready for assessment, however due to the lack of control handles provided by Google to manipulate the Quiz Mode, further refinement is required. The following procedure is required before releasing the assessment to the students: 1. Activate 'Quiz Mode' within Google Forms, 2. Assign Point values to the problems, 3. Select the correct answer (appears as the top choice by default) and randomize the order of the alternatives, and 4. Add feedback/solution when the student answers the question incorrectly. Google Forms also allows users to randomize the problem order to further discourage information misuse during the assessment. Once completed, instructors release the cloud-based form to the students in the form of a URL. The students can access the assessment using their smartphone browser or their laptops, regardless of operating system.

E. *Post-Assessment*

Automated-grading allows students to receive their scores with feedback immediately after submitting their responses. From an instructor's perspective, the submissions arrive as soon as students finally submit their responses, providing a live-view score distribution for the class (similar to the example shown in Fig. 5(a)). If instructors choose to, they can close the form submission when the allocated assessment period is over. Instructors must warn students because their selections will be lost if not submitted before 'close'. Following submission, the instructor can view problem-level statistics similar to the example shown in Fig. 5(b) for the representative heat transfer problem. The final scores can be exported to a spreadsheet or a gradebook.



(a)



(b)

Figure 5. Google Forms summary provides (a) instant score distribution for the assessment, along with (b) problem-level statistics for the class.

Furthermore, instructors can provide individualized feedback where necessary. Instantaneously presenting students with such feedback and solutions mitigates lingering misconceptions and reinforces their concepts. Descriptive feedback and solutions are paramount for student material retention.

III. IMPLEMENTATION

To explore the utility of complex multiple choice questions generated using Quipid in a traditional engineering course, the Mechanical Engineering Thermal-Fluid Sciences course series was selected. Thermal-Fluid Sciences is an integrated course that combines Thermodynamics, Fluid Mechanics and Heat Transfer into a year-long (two-term) course series in the junior year of the undergraduate program at Rowan University. Traditionally, this course involved paper-based quizzes with extended problems that required multiple mathematical steps to arrive at a solution. The implementation of Qupid required transforming these traditional 'workout' problems into stepwise problems conducive to multiple-choice format (without partial credit opportunities). Care was taken to reformat the quizzes without drastically changing the underlying assessment objectives, concepts, and in many cases the problem statements. The goal of this implementation was to gain preliminary insights, rather than the quantitative measure of the impact. The intent was to test and improve assessment material, assessment administration, and to refine feedback. At a secondary level, the implementation was used to gain insights into student behavior and attitude towards a smart-phone based assessment platform and its ability to provide instantaneous grades and feedback.

For the Fall 2016 term, 35 students were enrolled into the Thermal-Fluid Science section taught by the author. After the first paper-based quiz, five additional quizzes were administered using Quipid. The first paper-based quiz was kept the same across the years with identical problems to help the comparison. For the online-quizzes, students were asked to bring their personal smartphones to class fully-charged. Additionally, students were asked to lay their phones flat on the table to avoid revealing their choices to the students around them. The Google Forms links were shared at the beginning of the period via an email. Quiz preamble included an honor code statement that the students had to agree before proceeding. The honor code statement was inspired by Dan Arielly's studies on cheating [22] to discourage misuse. The alternatives were randomized between students to further limit dishonest behaviors. Students were allowed to use scrap paper to carry out their work, which was not collected at the end of the assessment. The quizzes were proctored by the instructor who was available to answer any clarifying questions.

IV. RESULTS

Figure 7 provides a comparison of average scores for every quiz since the Fall 2014 term. Considering the problems were nominally the same, Fig. 7 suggests the implementation hardly affected student performance when compared to paper-based quizzes. The results may even suggest a successful problem format transformation from 'workout'-based assessment to stepwise multiple-choice format, however this was not systematically studied. It is important to note that Quiz 6 was administered as a remote quiz. Meaning, students were able to take the quiz remotely, synchronously during the quiz period. While no evidence of misuse of resources was found, the dramatic improvement in scores for Quiz 6 for Fall 2016 remains conspicuous.

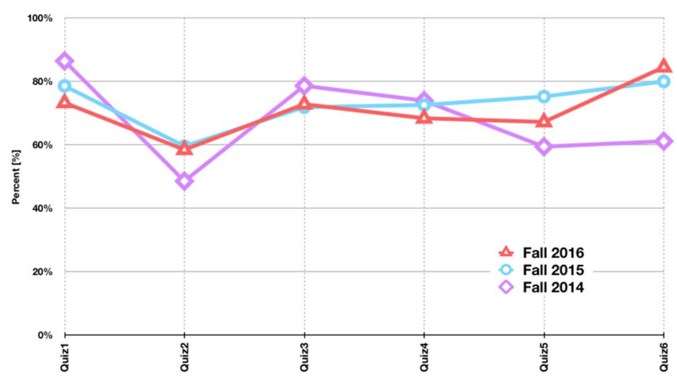


Figure 7. Comparison of quiz scores across three terms since Fall 2014. Quiz 1 was administered as a paper-based quiz and the content was identical across the years. For the Fall 2016 term, quizzes 2 through 6 were administered using Quipid.

A. *Instructor Observations*

Instructor observations are summarized here for the exploratory implementation of Quipid. Although the benefit of automated grading was inherent to the development of this solution, there were a number of unanticipated benefits that are listed here.

Academic Dishonesty. Being aware of the students' ability to misuse the smartphone to research quiz problems, the instructor was extra vigilant during quizzes. On the contrary, no evidence of dishonest behavior was recorded involving smartphones. This was partly attributed to the limited time available to respond to the questions.

Student Engagement. The instantaneous scoring and feedback notably promoted students seeking clarifications after the assessment. While qualitative, past students rarely sought such clarifications. Instead, in the past students congregated in the hallways to discuss the answers with their fellow classmates.

Quantified Misconceptions. Using the statistics, the instructor could identify major misconceptions and address them immediately. Elimination of manual grading also afforded instructor time to provide individual feedback to the students via Google Forms.

Digital Benefits. Due to the dynamic properties of cloud-based platforms, the problems could be edited and updated right up to the quiz administration. In fact, an error was corrected during one of the quizzes. Time allocated to quiz distribution and collection was eliminated from the quiz period providing extra time for students. The embedded solutions also eliminated generating a solution key for each problem.

B. Student Feedback

Students were surveyed to share their experience with smartphone based quizzes. The survey was kept open-ended where students were free to comment on the new assessment method anonymously via an online form. In-class discussions also highlighted some concerns and benefits of the new approach. Below are the three themes that emerged from the student feedback, described with a representative quote from the student survey.

Rapid Feedback. Students overwhelmingly preferred instantaneous scoring and feedback on their performance. Several students specifically commented on the significance of this feature as the key benefit. Few students even acknowledging its superiority over paper-based quizzes returned later.

1) *"I think the online quiz worked well, I didn't have any issues with it. I liked being able to see my score and the correct answers immediately. I can't think of any changes I'd like to suggest."*

Going Paperless. A few of students noted the preference for paper-based quizzes because of its simple navigation (as opposed to scrolling Google Forms quiz). On the other hand, many students were also neutral to any preference as far as assessment format goes.

2) *"Online format is good. Positive is the immediate feedback. Negative is without printout navigation and time management become more difficult."*

Partial Credits. By far the most frequently commented topic was related to the lack of partial credits. Students felt that the online submission did not adequately provide opportunities to gain partial credit on their work, which would have eventually helped their performance.

3) *"I believe the concept of the online quiz is a great idea as it was simple to use and provided the quiz taker with all multiple choice which helped me personally set a path on how to solve the problem. One thing I did not like about the online quiz was the lack of partial credit."*

V. DISCUSSION

Based on instructor and student responses, rapid feedback was perceived as the greatest strength of Quipid-based assessments. In addition, the ability to edit problems with a simple change to the problem formulation greatly benefits the creation of future assessments. Problem-level statistics provides quantitative instructor guidance to refine future assessments. With regards to the partial credits concerns raised by the students, it is important to note their overall performance on similar assessments (when compared to past terms with existence of partial credit) was evidently unaffected. This outcome is likely due to the assessment reformatting with limited cascading problems and stepwise solution approach. Thus by distributing the assessment weight over the quiz, the need for partial credit was effectively eliminated. Yet, the students attributed their poor performance on the lack of partial credits, even though their average scores were marginally higher than some past assessments.

While Quipid automates the critical aspects of assessment generation, namely creating a Google Forms quiz, there are several minor steps that need to be manually executed. These minor steps can be easily scripted as long as Google adds the dedicated functions. Until then, Quipid is a proof-of-concept tool with an appreciable potential to evolve into a revolutionary assessment tool. A final refined version of Quipid will be released as a Google Add-on where instructors can easily use Quipid to generate assessments and empower classrooms with rapid feedback.

VI. CONCLUSION

While rapid feedback has been demonstrated as a powerful pedagogical tool, its use is less common within STEM fields. The challenge often is associated with assessment generation. Specifically, how the assessments cannot be altered without considerable effort. Quipid addresses this problem by embedding formulation within the assessment generation procedure. Instructors can now change problem parameters and quickly develop new assessment problems with corresponding alternatives. Quipid uses the familiar spreadsheet interface to develop problems and Google Forms to administer the assessments. Students receive their scores and feedback immediately following an assessment. Overall, the implementation of Quipid within a junior-level, math-intensive, course was a success both from the student and instructor's perspective. The exploratory study using Quipid produced promising outcomes ranging from a positive student response for rapid feedback and procedural insights on administering smartphone-based quizzes.

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