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Reflections on the Implementation of Short, Authentic Oral Assessments in a University Manufacturing Course

Sandra Walter Huffman, Massachusetts Institute of Technology

Sandra is a fourth-year Interdisciplinary PhD Candidate at MIT (expected Graduation May 2025). She studies Engineering Education, specifically the development of undergraduate engineering students' modeling practices, and is based in the Department of Mechanical Engineering.

Kaitlyn Becker, Massachusetts Institute of Technology
Dr. John Liu, Massachusetts Institute of Technology

Dr. John Liu is the Director and Principal Investigator of the MIT Learning Engineering and Practice (LEAP) Group, which investigates the intersection of learning technologies, STEM workforce and education, and digital learning and MOOCs. He is a Lecturer in MIT's Mechanical Engineering department and a Scientist in the MIT Digital Learning Lab. He leads education and workforce development efforts for MIT's new initiative: Manufacturing@MIT. He was the Director of the Principles of Manufacturing MicroMasters program, an online certificate program that has now enrolled over 200,000 learners across the globe. He has received several Best Paper Awards from ASEE and IEEE DEMOCon. He has co-authored dozens of publications and currently serves as an executive guest editor for Manufacturing Letters. His research is supported by the Department of Commerce, Department of Defense, Massachusetts Technology Collaborative, Schmidt Futures, National Science Foundation, MIT, and industry partners.

Prof. Warren P. Seering, Massachusetts Institute of Technology
Rebecca E Zubajlo, Massachusetts Institute of Technology

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1) Introduction: Why Authentic Exams? Why this class?

Most technical engineering assessments are high-stakes written exams where student success depends on finding correct, numerical answers to well-defined, single-solution problems [1], [2], [3]. These problems are distinct from the ill-defined, open-ended problems common in engineering jobs [2]. To solve "real-world" engineering problems, students must develop the practices of engineers: the ability to interpret data, identify and conceptualize complex engineering problems, apply engineering judgment, and communicate with the broader engineering community [2], [4], [5], [6], [7], [8]. These practices align with current ABET accreditation requirements [4], but are generally not developed through traditional assessment [7], [9], [10], [11], [12]. Authentic assessment is one solution to this misalignment [13], [14]. It is an assessment method designed to mimic the types of tasks engineers may face in "real life" engineering scenarios and push students to practice competencies likely necessary for their careers [13].

In this paper, we chronicle the process of implementing authentic oral assessments in an undergraduate manufacturing class and describe the key reflections and considerations we feel are important for educators to contemplate if they are interested in implementing similar interventions. This course was chosen for this intervention because of the aspirations of the lead Professor, Kaitlyn Becker who seeks to align her course with well-researched practices through incremental improvement. These motivations align with departmental concerns that students are ill-prepared for oral assessments. Before this intervention, her course, 2.008: Design and Manufacturing II*,* included lecture and lab portions with many graded assignments from each component, and one written exam mid-semester.

Authentic assessment, in the form of two short, oral assessments, was chosen to replace short, weekly, in-class quizzes. The assessments, conducted during labs, would help save class time and would cover topics from multiple lectures and laboratory applications. Additionally, the teaching team believed (and promoted the idea that) oral assessments could help incentivise increased collaborative discussion and question-asking during class time as a way to practice the skills needed to succeed in the assessment. All students took both oral assessments.

Implementing authentic assessment can be difficult in any classroom. Most instructors have exclusively attended and taught courses with traditional assessment, and do not have the time or training required to transition [15], [16]. Pedagogical change is not often incentivised by faculty or departmental administration [15]. Additionally, students tend to react negatively to educational interventions outside of their norms and expectations [2], [7], [17], [18], [19].

In this course, instructors met - and overcame - these barriers. The following sections describe the process of creating the oral assessments, example questions, our grading rubrics, and our reflections on various aspects of the process. We hope our insights can serve as a guide for instructors looking to implement similar assessments and hope that we can demystify the processes and encourage others to try this type of authentic assessment in their classrooms.

2) Author Backgrounds

This intervention was a collaboration between course instructors, teaching assistants, and an engineering education researcher. Our backgrounds influenced our decisions, how we see teaching and learning, and our reflections through this process. Below is a short summary of each of our relevant backgrounds.

Kaitlyn Becker is an Assistant Professor in the Mechanical Engineering Department at MIT. She has served in various teaching capacities from undergraduate instructor to lead instructor of courses in design and manufacturing in the departments of mechanical engineering and materials science at MIT over the course of eighteen years. Her PhD research and current lab focus on projects at the intersection of design and manufacturing, with challenging materials and environments. For five years prior to graduate study, she worked as a manufacturing engineer in the medical device and microfabrication industries. This time in industry, combined with her experience as an undergraduate student taking the same course, as well as family members specializing in education careers have influenced how she approaches teaching.

John Liu is a Lecturer in the Mechanical Engineering Department at MIT. His current lab focuses on the intersection of learning technologies, STEM workforce and education, and digital learning and Massive Open Online Courses (MOOCs). He has been involved with supporting various courses in mechanical engineering and physics at MIT, and had recently led the development of a first-year course to introduce manufacturing to first year students.

Rebecca Zubajlo is a Mechanical Engineering doctoral candidate at MIT, specializing in the intersection of biology, design, and manufacturing. She has served as a teaching assistant for this course three times, including its graduate version, as well as many other engineering courses which included the administration of oral assessments. With teaching certificates in curriculum design and early childhood education, she has also instructed courses and outreach programs for learners from preschool to graduate students. Having taken the graduate version of this course herself along with oral assessments, her dual perspective as a student and instructor informs her commitment to enhancing learning opportunities.

Sandra Huffman is a graduate researcher studying Engineering Education. She focuses on closing the separation between what is asked of students in technical engineering classes and the expected competencies of the workforce. As an undergraduate, she took 2.008: Design and Manufacturing II. Her past experiences in the course, her research interests, her teaching experience, and her inclination towards educational advocacy all shaped her approach to designing and implementing interventions for this course.

3) Creating and Giving the Oral Assessments:

The teaching team believes it is crucial for the oral assessments to fit within existing class structures. The in-person class time — a weekly three-hour block — utilizes a flipped classroom format: students watch videos and answer concept questions outside of class, then work together in class to solve problems after a brief content review [20]. Most lecture problems surround the investigation of physical artifacts. An example of an artifact and corresponding problems is shown in Appendix 1. Instructors and TAs attend class time to check in with students and answer questions. In a previous semester, 30-minute recall-focused quizzes were given at the beginning of each class to assess the students on content from the previous week. These quizzes shortened in-class collaborative time and were difficult to manage with extended time and other accommodations needs. Therefore, oral assessments were chosen to replace this course component. Students took the first oral assessment during week six of the semester and the second oral assessment during week nine of the semester.

In the following sections, we will explore the process taken to create the exams, outline exam logistics, and take a detailed look at each oral assessment.

3.1) Problem Creation and Revision:
Before problem creation for the oral assessment, the lead instructor had conversations with current design and manufacturing engineers from industry and reflected on her own experiences working in industry and conducting technical interviews. She also spoke with past students and other faculty members about giving oral assessments. These conversations shaped how she crafted assessment problems and presented the exam to her students.

Each exam was based on a product or group of products currently being mass-manufactured and covers a different set of engineering competencies. As will be discussed in future sections, the first oral assessment centered around design for manufacture, taking into account trade offs related to process parameters; the second focused on data interpretation and problem-solving related to process variation. The lead instructor, Professor Kaitlyn Becker, started problem creation for the oral assessment by brainstorming products that she found both familiar and compelling, and creating baseline questions for each. She and the researcher then narrowed down topics. The instructors suspect that ideas not chosen this year will be used in future years.

From there, questions and a rubric were co-created. Professor Becker identified the types of competencies she wanted students to demonstrate, but had never made a qualitative rubric before. Therefore, the researcher and lead instructor worked together to create a rubric draft, paying particular attention to competencies that are (1) important to authentic engineering practice and (2) could be reasonably expected based on course content and in class activities. Rubric creation helped distill and solidify assessment aims, which in turn helped instructors create stronger questions.

Once a rubric and question banks were created and revised by both instructors, the teaching team conducted practice oral assessments with (1) students who had taken the class in previous years and (2) TAs and instructors taking turns in asking questions and acting as students. Questions and rubric wording were revised and finalized. Practice oral assessments always ran faster than the actual assessments, likely due to higher familiarity with the material and lower stress levels of the course staff and course alumni serving as practice subjects. Practice with intentionally confusing or outlandish answers improved instructor preparation and helped build intuition for expected response length.

3.2) Assessment Logistics:
Each oral assessment was administered over the course of one week, with students taking the assessment during part of their regularly scheduled lab time. The rubric was given to students about one week in advance of their oral assessment. Assessments took place in an office next to the lab workshop. Before the beginning of each lab section, a paper with each student's exam

time was posted on the door. The first assessment was scheduled to start ten minutes into the normal lab time. There were seven lab sections, each with six or twelve students for a total of about 60 students. Figure 1 shows the setup of the assessment room.

Figure 1: Oral Assessment Space

Two members of the teaching team sat on the left side of the table, and the student sat on the right. All materials needed for the oral assessments were provided on the table. The two instructors co-administered and graded the first hour of the first lab section to calibrate their grading and align oral assessments deliveries. For all other lab sections, an instructor asked exam questions and a TA took notes. Instructor and TA schedules dictated who administered exams for which sections.

Unless a student requested no recording, all oral assessments were recorded. This allowed for students to review their oral assessments with a staff member if they wanted to better understand their performance. It also allowed course staff to go back and look at moments that they missed, re-grade in the case of grade drift over time, and attempt to reduce grading bias.

3.3) Oral Assessment 1:

Oral assessment 1 focused on single-serve yogurt cups, that were identifiably injection molded or thermoformed. For each assessment, instructors picked one to three cups out of a pile, shown in Figure 2, to discuss during the oral assessment.

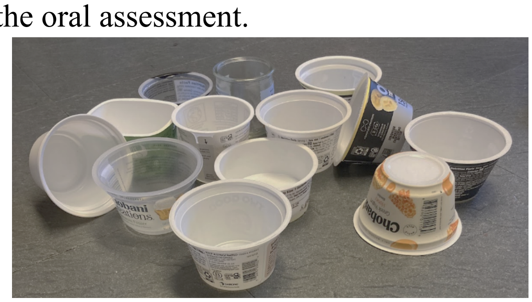

Figure 2: Yogurt cups used in Oral Assessment 1

For the first oral assessment, the following competencies were emphasized:

- CRQFS: Describing the tradeoffs between Cost, Rate, Quality, Flexibility, and Sustainability for different manufacturing processes.

- Design for Manufacture: Explaining the connections between design decisions and manufacturing processes, weighing tradoffs, and using engineering judgment to make suggestions.
- Processes and Parameters: Identifying manufacturing processes and process parameters, and making context-dependent conclusions about the direction and degree of the effect of modifying those parameters.
- Communication: Communicating clearly with appropriate discipline-specific language and articulating gaps in understanding, navigating a path forward when appropriate.

The oral assessments were each graded on a 5-point rubric, which can be found in Appendix 2. Grades were entered in google forms and an average of the four rubric points was used as the final grade. The TAs also took notes during the exam which were used to provide feedback to the students alongside their grade.

All oral assessments started by asking students how the yogurt cups were made and then asking them to explain how they came to that conclusion. Then, the conversation moved to CRQFS trade-offs; students were prompted to compare how two CRQFS aspects were related in the context of the yogurt cup(s). They were then asked to make a quick sketch of a mold for one of the cups. Conversation centered around the location of important features, artifacts from the manufacturing process, and reasoning behind student decisions. Lastly, instructors initiated a conversation around a specific design decision and how that related to different process capabilities and parameters.

Examples are listed below:

- If I wanted to make these cups stiffer, what could I do?
    - How would that affect [pick one of the CQRFSs]?
    - Have you ever seen that [referring to student response] in a yogurt cup? Why might that be?
- If I was concerned about the cost of the cup, what could you do?
    - What are the limitations of that?
- If customers complained about the squishiness of the cup, what would you do?
    - How would that affect the process? What are the limitations?
- What sort of defect would you expect if the injection molding pressure were too high?
    - What are some process limitations associated with either process and what effects will occur if you push those limitations?
- How would I make this cup look more expensive?
    - How would that affect [pick one or more of the CQRFSs]?

All questions had several possible correct answers and many possible directions for students to explore. If possible, instructors would reference back to the students' drawing of the mold, asking questions about specific aspects. For instance, when discussing injection molding, an instructor may ask, "if we made it thinner here [pointing], would the injection pressure need to be higher, lower, or stay the same," "do you think the temperature is higher here [pointing] or here [pointing], " or "can you trace the length you're referring to on your drawing?" Instructors thanked and/or congratulated each student on completing the exam. Before calling in the next student, they took two to three minutes to check in with each other and confirm a grade and feedback for the student.

3.4) Oral Assessment 2:
Oral assessment 2 focused on the midsole of 3D-printed Adidas® shoes shown in Figure 3 (left) and fictionalized data about the part (right).

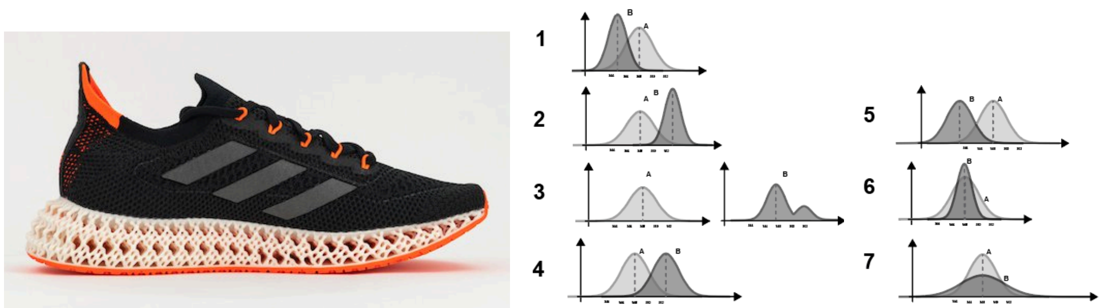

Figure 3: Left: Shoe used in Oral Assessment 2; Right: data distributions used in Oral Assessment 2. Seven data sets are shown, but each student received only one

The shoe was provided in the exam room, and each student was given one of the seven data sets to analyse and discuss. All datasets show the same distribution “A” which represents the idealized distribution of the mass of midsoles produced over a six month time frame about a year in the past. This type of data is representative of actual inspection processes where weight is monitored for process control. Each graph has a unique data set “B” which represents a newer set of data for the student to compare and discuss.

The following competencies were emphasized in this oral assessment:

- Manufacturing processes: Identifying the manufacturing processes and providing observations or reasoning to support conclusions. Articulating how key features of the object would change if it were made other ways.
- Data Interpretation: Identifying characteristics of a normal distribution curve and connecting those characteristics to the given context to make relevant conclusions from the data.
- Process Variation and Problem Solving: Imagining potential causes of data variation for the context and describing the relative magnitude of different effects. Proposing specific solutions for characterization and mitigation of the source(s) of variation.
- Communication: Communicating clearly with appropriate discipline-specific language and articulating gaps in understanding, navigating a path forward when appropriate.

Oral Assessment 2 was graded the same way as Oral Assessment 1. The finalized Oral Assessment 2 rubric can be found in Appendix 3.

All oral assessments began with just the shoe. The instructor asked students to investigate the midsole, determine its manufacturing process, and explain how they came to their chosen conclusion. The process described by the student was taken up by the instructors as the process of discussion regardless of correctness. Students were then asked to look at a graph of only distribution “A” and identify several fundamental statistical characteristics (average, standard deviation, etc). Instructors then presented one of the seven graphs with both distributions “A” and “B” and told a short fictionalized story of where this data came from. The rest of the time was spent on data interpretation: *What are possible explanations for the difference between the* *distributions? How would you test to see if that is the case? Do you think that would account for all of the difference? If you could make recommendations for next steps to the process engineers, what would you suggest? Etc.* Follow-up questions and elaboration were interwoven into the conversation. A student's final recommendation on process improvement concluded the assessment.

3.5) Building Student Buy-In:

Building student buy-in was vital to successful exams. Starting from the first lecture, instructors explained the goals of the oral assessment, how authentic assessment can be beneficial for student development, and what students could do to prepare. Specifically, the instructors explained that the assessment questions were designed to simulate technical questions asked by clients and coworkers in professional settings, job interview questions, and/or some types of questions asked in doctoral qualifying exams. This was motivated, in part, by conversations with past students who were initially sceptical of and intimidated by oral assessments, but believed they could be useful in preparing for their job search. Overlapping practices between in-class small-group discussion based activities and the oral assessment allowed students to start developing their skills from day one. Instructors communicated that the questions in the oral assessment would be linked to the content of the in-class activities. They tried to dispel the notion that authentic assessment equates to random questions, reassuring students that they would not ask questions that were completely out of the blue. Similarly, they communicated that there would be high, but achievable expectations for students so there was motivation for students to engage in the process of building their skills.

Students were also given several opportunities to practice with instructors. During office hours, students had the option to come in for a “mock” oral assessment to practice and receive feedback. Additionally, instructors and teaching assistants ran a demonstration at the end of one lecture where the professor played the role of a student and teaching assistants played the role of interviewer, asking questions similar to those they might expect in a real oral assessment. After this demo, the students were given the opportunity to ask the processor additional mock assessment questions, which they eagerly accepted. Student feedback for this activity was quite positive and appeared to reduce anxiety around the exams.

4) Reflections:

In the following subsections, we outline general reflections, attempt to answer several questions relevant to the incorporation of authentic oral assessments, and compare and contrast the oral assessments with the written assessment given in the same class. The questions include *Were the exams Actually Authentic?, Can You Grade a 7-Minute Oral Assessment Effectively?,* and *Was there Bias in Grading?* Additionally, we highlight one TA’s perspective on these oral assessments informed by her experience in past semesters of this course and involvement with past oral assessments in this and other classes.

4.1) Overall Reflections:

Impact on Classroom Experience: Instructors who had taught the class in past semesters noticed a change in the way students engaged with in-class activities this term. This year, students were more likely to have discussions with the teaching team and were, on average, more curious about the *why* behind the material. Instructors believed this was, at least in part, due to the connection between the in class activities and the oral assessments. Because students could see the grade-related value of technical conversation, they were more likely to engage in it. When there were just written assessments, students seemed more likely to avoid discussion and rush through workbooks. This shift in behavior was exciting to the teaching team as it made classroom time more engaging as it shifted interactions from one-sided questions to more collaborative problem-solving discussion between students and course staff.

Cheating: Because different students were taking the exam over the course of a week, it was possible for students to learn about the exam before they came in. To mitigate this, rotating question banks were created and instructors always asked follow-up questions about *why* a student answered a specific way or *how* they knew something to be true. Over the course of the week of the first oral assessment, instructors began to suspect cheating because some students would answer the questions before closely inspecting the yogurt cup. Different cups (with different manufacturing methods) were randomly selected from the pile each time, but there were a couple students who confidently stated the same, (often incorrect) answer without taking time to look at the cups. Students with a stronger mastery of the subject material could always explain their answer or correct themselves while those with poor mastery were not able to continue the conversation. In the second oral assessment, the instructors reminded students not to discuss the assessments and assigned distinct distributions to each lab section, as the possible cause(s) behind each distribution change could be different.

Grading and Grade Spread: Grade distribution met instructors expectations for a quality assessment tool. While smaller for the second than the first oral assessment, the grade spread visually distinguished higher performing and lower performing students in a way that the instructors believed aligned with content understanding. Instructors were equally surprised that no students asked for re-grades or asked to view/go over their oral assessment videos. It is unclear if this will be the case in future semesters.

Scheduling: Scheduling exams was straightforward because the oral assessments took place during already scheduled lab time. However, this meant instructor time was spread throughout the week. For future semesters, instructors are considering condensing the oral assessments to fewer days and having students sign up for time slots. Preference on this matter will depend on the individual instructors. Rescheduling exams was significantly easier for the oral assessments than for the written exam. This reduced stress for both students and staff when a make-up exam was necessary.

On “Word Salad”: As is often seen on written exams, some students came into the assessment spewing “word salad,” stringing together unrelated concepts and words that sounded technical but did not make sense. This was difficult for instructors because in addition to being difficult to interpret, word salad also contributed to overly lengthy answers. Instructors had to practice cutting off and redirecting students after a reasonable amount of time and making sure students knew that word salad would only hurt them in the oral assessments; part of what the teaching team is evaluating is that students are able to evaluate and filter for what information is most relevant. Between the first and second oral assessments, the teaching team clarified this to students and made sure to note that it was always ok to ask clarifying questions both about what was being asked and if more information was required to answer the question. In these assessments, there was a clear difference between word salad and mixing up words. Some students were able to convey understanding by describing the importance of certain process parameters and identifying features of a product but would occasionally flip the direction of a ratio or use an incorrect word. As long as the student could convey the correct conceptual understanding, the minor mix-up was not heavily penalized but was included in their feedback. Student Stress and Self-Confidence: Like for any exam, students were anxious about their performance. As part of obtaining student buy-in, the teaching team attempted to reduce this as much as possible. While students did exhibit nervous behavior such as picking nails, flushed cheeks, or disassembling pens, student anxiety levels appeared lower than what several colleagues experienced and warned about in their own oral assessment for other courses. Instructors were impressed by student performance, but there were some concerns about how grades affected student confidence. While a four out of five was considered a strong grade by the teaching team and would likely contribute to an A in the class, several students interpreted it as a low grade: equivalent to a B minus. The instructors anticipated this and explicitly discussed it in advance of the first quiz, but it will likely need to be reinforced after each quiz in the future. Alternatively, the rubric could be adapted in the future as a way to improve self-efficacy.

4.2) Were the exams Actually Authentic?

Unlike traditional schooling practices where engineering is presented as a solitary, organized, objective application of principles and equations, authentic engineering practice is a complex conglomeration of socio-technical attributes [21]. Engineers work towards the goal of solving a problem. Problem types can include decision-making between a fixed set of options, troubleshooting, open-ended design, diagnosis-solution problems and more [2]. These problems are often ill-defined and include ambiguity, complexity, contradictions, and tradeoffs [21]. Problems must be solved collaboratively; engineers will use discipline specific language and norms to communicate and negotiate details with peers, supervisors, reports, and clients [9], [21]. Engineers often rely on inscriptions: domain-specific sketches, figures, diagrams, and charts to think through and communicate their ideas, [22] and interpret noisy data in a way that allows them to productively progress in the project [9].

The oral assessments were designed to replicate authentic engineering practice. In the first oral assessment, students had to draw a possible mold for the yogurt cup and use it to communicate design attributes. They also had to weigh the tradeoffs of different design decisions and make suggestions based on their understanding of process parameters, design attributes, and their own engineering judgment. In the second oral assessment, the students had to interpret data in order to diagnose and solve a potential problem. They had to think through a troubleshooting process and make a plan that tested their ideas. In both oral assessments, the students had to work within a context-specific motivation with flexibility and nuance, and were assessed on their domain-specific technical communication and use of appropriate jargon.

In engineering work, “the social and technical are almost inextricably tied up together in any engineering project, at least in any project that is realized successfully” [20, pg 121]. Because the oral assessments were individual assessments, it was important to incorporate some collaborative socio-technical skills into the assessment. Students were expected to sensemake, persuade, and communicate as if the assessment were a conversation between engineers in industry. Accountability was enforced through follow-up questions. Additionally, both instructors had conversations with industry practitioners before and during assessment creation in an attempt to align questions with authentic engineering practices. These interactions, as well as past industry experiences, helped instructors write questions that reflected how students may be asked to apply knowledge on the job or could be reasonable oral interview questions for an introductory level job. The teaching team believes that, although one can never fully remove schooling culture from an assessment, the oral assessments were credibly authentic to engineering practice.

After the oral assessments, several members of the teaching team received feedback from students that the exams helped them prepare for and succeed in technical interviews. Although this does not provide insights into the oral assessments' authenticity relating to everyday engineering practices, it does demonstrate authenticity relating to the expected competencies and career progression of practicing engineers.

4.3) Can You Grade a 7-Minute Oral Assessment Effectively?

Like any new skill, creating, conducting, and grading a short oral assessment takes practice. During the first oral assessment, the assessment often went over on time and grading nuances were difficult to navigate, leading to extended discussion time in between exams. This was especially true for low-scoring students for whom instructors struggled to find points, but felt bad about assigning a low grade. Over the course of the week, instructors experimented with bolding different rubric words to help quickly differentiate between blocks, but did not ultimately settle on a preferred format. Between the first and second oral assessment, instructors edited the rubric so that points were more evenly spaced and distinguishing between points was easier. One change that made the exam significantly smoother was shifting the TA role from question-asker to note-taker. This occurred early on in the first oral assessment and helped create a more focused job for each facilitator. Having one person focused on record keeping and one focused on succinct exam progression decreased confusion, increased confidence in score consistency, and allowed for quick assessment of student responses.

Additionally, instructors improved their question creation skills from the first to second oral assessment by structuring questions more clearly around each vector of the rubric, creating questions that did not need a "right" answer to move forward, and trimming down the problem made the seven minute time more consistently achievable. Ultimately, as the professors increased their fluency with the rubric and became more comfortable knowing when and how to move the assessment forward, they became faster at assigning grades. For the second oral assessment, the instructors felt that the timing was a lot better and the assessment went more smoothly. Instructors feel that the skills they built this semester will transfer to future semesters, making the process easier and faster in the future. Instructors believe that oral assessment grades fairly represented both student performance and matched their perceived understanding from other activities and assessments. There was a wide spread of grades and they did not drift over time or by instructor, indicating grades could be fairly assigned for the 7-minute oral assessment.

There was disagreement among instructors about if a longer exam would be better and what "better" meant in the context of this exam. Both instructors and students had to be "on" and focused for the entire exam. Would a longer exam be more exhausting or give everyone a chance to relax? It is common for test anxiety to hinder student ability in written exams ordering any length; would a longer exam reduce exam anxiety for an oral assessment? Would a longer exam give students a chance to gather their thoughts to speak more precisely or would it allow more time to produce a "word salad" of unconnected technical gibberish? These questions remain incompletely explored and answers likely vary from student to student.

For this class size, every additional exam minute would result in an hour of extra instructor and TA time. From this perspective, the shortest possible exam time would be better. If this oral assessment is meant to replicate part of a design review, a technical interview, or a quick hallway conversation in an engineering firm, the time crunch is likely appropriate. If it is meant to replicate a long co-working session or doctoral exams, a longer exam may be more appropriate. In future years, instructors are likely to keep the 7-minute exam. However, there is a small chance they will extend it to 9 or 10 minutes, particularly in semesters with lower enrollment.

4.4) Was there Bias in Grading?

All exams have bias. This ranges from question wording and diagram use that favors those fluent in American academia to hidden cultural signposts that only cue the dominant student group. The teaching team tried to reduce bias in several ways. To calibrate grading and get the instructors comfortable with the questions and rubric, practice exams were conducted with students who had taken the class in past semesters. Their feedback from the experience was incorporated into testing practices. The first hour of exams was also given by both instructors to calibrate further. Grade averages were checked over the course of the testing week. Grades averages did not shift throughout the week and grades from each professor did not differ or drift.

Instructors and TAs also discussed possible biases and how to reduce them beforehand. The teaching team was aware of possible inherent biases around gender, presentation, voice/accent, presentation of confidence, and speech volume. While this cognisense can not completely eliminate these biases, it did serve to help reduce them. There were always two members of the course staff administering the exam: either two instructors or one instructor and one TA. Having two perspectives in the room helped catch things that one person might miss. All exams were recorded (no students chose to opt out of recording) in case a student wanted to go over their exam or get a re-grade. Additionally, instructors could go back and look at the videos to learn from their performance, spot-check grades, or re-grade in cases of grade drift.

The creation of consistent question banks and use of the rubric were incredibly important as a bias reduction tool. Question banks helped the instructors have a variety of questions of similar difficulty. Having question banks that corresponded to rubric skills helped instructors stay focused and have more consistent exams. Because the rubric was released before the exams, students knew what skills were being assessed, avoiding the type of information disparity that often constitutes the “hidden curriculum” of college campuses [23].

There were concerns among instructors that an oral assessment would bias students that are naturally better at thinking out loud. However, as discussed in previous sections, this type of exam incorporates sociotechnical practices (such as collaborative thinking/problem solving) that are prevalent in engineering practices but are often overlooked in undergraduate engineering education. Just as some people have a natural inclination towards memorization or have an intuition for a particular technical subject, so will some students have a natural tendency towards these verbal communication skills. Incentivising students to view this type of communication as a learned practice rather than an innate one — and develop these skills as part of this class — is a step towards a more comprehensive and representative education.

4.5) Comparing the Written and Oral Assessments

In addition to the two oral assessments, this course had a more traditional written exam. Instructors found the experiences of creating, giving, and grading these exams different in many ways. Below, Table 1 summarizes the similarities and differences between the written and oral assessments used in this class. These ideas are elaborated in the paragraphs below.

Table 1: Similarities and differences between the written- and oral- assessments

	Written Assessment	**Oral Assessment**
Time-constrained	✓ (3 hours)	✓ (7 minutes)
Ability to ask follow-ups/ clarifications	✕	✓
Can adjust mid assessment for student performance	✕	✓
Personal Interaction w/Students (relationship-building)	✕	✓
Flexibility in when and where grading takes place	✓	✕
Prep Time: *For this course, one written assessment took approximately the same amount of prep time as the two orals*		

<u>Student Understanding:</u> Instructors found that, in the oral assessments, they were more confident that students' grades represented their knowledge and understanding. In a written exam, instructors are not able to ask follow-up questions and often have to wade through a confusing excess of equations and writing. Instructors feel like when they graded the written exam, they had to mindread, often staring at a confusing answers for long periods of time wondering if it was confusing because the student writing was unclear, because the student didn't know the material and were trying to get partial credit, because the student misinterpreted the question, or because the question was overly confusing. Each of these problems could represent a different level of understanding in a student. Without a way to clarify, grading could feel haphazard. The oral assessments felt like it gave an advantage to both the students and instructors in this front, in that students could ask clarifying questions and elaborate on confusing points. Instructors could ask follow-up questions and quickly determine where confusion lies. Along these lines, there is more opportunity for word — or equation — salad on a longer written exam. As discussed in the general reflections section, the oral assessment does not lend itself well to students who try to spew word salad. However, students still try to throw every equation and/or explanation they know at a written problem in an attempt to get partial credit, leading to confusing answers. Additionally, there is no flexibility on a written exam. If a student comes into an oral assessment without much understanding of the course material, instructors can pivot to get a nuanced understanding of what competencies they *do* have. In a written exam there is no such flexibility, leading to both the student and the instructor grading their exam to express having a worse experience.

Oral assessments also allowed for better relationship building between students and instructors. Written exams are less personal; the day after grading instructors did not feel they had a good sense of what each student knew. However, after the oral assessments, instructors felt like they knew where each student stood and could better adapt their classroom conversations to each student. Being able to contextualize each student also meant instructors felt more comfortable doing things like writing letters of recommendation where they knew each student's strengths rather than just the number they scored on an exam. Some of the lead instructors' favorite moments were getting to know students and giving them space to come up with more nuanced answers than they had ever seen in a written exam. There were some opportunities, particularly if the student was ahead of time and doing well in the oral assessment, to ask longer open-ended questions or questions instructors viewed as "trickier" to see where students took them. Getting a (sometimes surprising) answer of "that depends" with a reasonable explanation was a particularly rewarding experience for the teaching team, seeing a transition from the role of a student to that of an engineer. Additionally, some students were more chatty after the oral assessments, a couple even stayed after to chat about the product and about manufacturing more generally. The requirement of direct conversation with instructors seemed to break barriers and open up more communication in the classroom and office hours. It is the instructors' hope that this enthusiasm leads to increased understanding as well as stronger educational relationships.

<u>Instructor Time:</u> There is a common perception that oral assessments take more time than written exams. For this course, the lead instructor kept track of all the teaching team hours that went into creating, revising, giving, grading, and conducting make-up exams and found that it took approximately the same amount of time for two oral assessments as it did for one written exam. This was largely due to extensive time revising written problems, organizing/giving make-up exams, and grading. However, this time was not evenly distributed between course staff, and instructors noted that not all hours of the day are worth the same. For the written exam, problem creation and grading were flexible hours that could be done on weekends or evenings, leaving daytime hours for other meetings. However, the oral assessment took place during inflexible workday hours. While some members of the teaching team were able to effectively shift their week's schedule to fit in the oral assessments, others found that this type of work disrupted their other responsibilities for the week. Proctoring a written exam was also a different level of attention than giving the oral assessments. For the written exams, some instructors could work while others answered student questions. But for oral assessments, both the instructor and TA needed to be on and focused for the entire length of the exam. Overall, the teaching team preferred the student interaction that came with the oral assessments over the individual work of grading written exams.

After having both the oral and written assessments, the teaching team is considering shortening or removing the written exam for future semesters.

4.6) Comparing this Process to Other Oral Assessments: a TA's Perspective

Rebecca Zubajlo, one of the TAs for this course, has significant experience with oral assessments, having both taken and administered them in various technical courses. In the context of manufacturing education, she has now conducted oral assessments in collaboration with three distinct sets of teaching staff—one set of graduate course instructors and two sets of undergraduate course instructors. Several distinctive factors set this oral assessment experience apart, contributing to its effectiveness, fairness, and reduced potential for bias. These factors include: (1) fostering student buy-in and engagement, (2) employing a comprehensive rubric, (3) addressing and mitigating bias, and (4) designing concrete, problem-focused exam content.

Achieving student buy-in was pivotal for the success of these oral assessments. The instructional staff provided clear explanations of the purpose of the exams citing conversations with alumni and other course instructors, highlighting their role in fostering critical skills essential for post-graduation success. Structured opportunities for practice, including group activities, individual exercises, and a demonstration oral assessment conducted by the professor, helped students understand the value of the process. This approach not only motivated students but also empowered them to take ownership of their learning with a worked example and invest effort into mastering the oral assessment format.

The detailed rubric served two purposes: (1) allowed students to fully understand evaluation metrics and (2) reduced variability and bias in grading. As bias (racial, gender, personality, etc.) in oral assessments is a potential problem and can create unfair grading for students, we sought to reduce this possibility. The rubric coupled with the instructional staff being aware of bias and open to discussion during the entire process created an environment to converse about potential issues and create more fair grading for all students.

A well-defined rubric served as a cornerstone of the exam process, achieving two critical goals: (1) ensuring that students fully understood the evaluation criteria and (2) minimizing grading variability and potential bias. Recognizing that biases (e.g., racial, gender-based, socio-economic, personality-based, etc.) can influence oral assessments, the instructional team took proactive steps to mitigate these risks. The rubric provided a standardized framework for assessment, while ongoing discussions among the teaching staff fostered awareness of bias and created a collaborative environment for addressing potential concerns. This deliberate approach ensured a fair and transparent evaluation process for all students.

The oral assessment problems were carefully constructed to assess students' critical thinking and problem-solving abilities. Each problem was designed to align with content delivered through diverse instructional formats—video lectures, in-person lectures, hands-on labs, and guided in-class assignments. This multifaceted exposure enabled students to draw on a range of prior learning experiences and apply their knowledge dynamically during the oral assessments. The instructors intentionally conducted the exams to highlight what students understood and could demonstrate, rather than focusing on uncovering gaps in their knowledge. This shift encouraged students to draw more confidently on their existing knowledge and skills to arrive at solutions. By engaging with content in varied ways throughout the course, students were better equipped to demonstrate their understanding and adaptability in solving real-world challenges.

In prior oral assessment experiences, the absence of some or all of these critical factors often left students feeling that the exams were unfair or unproductive. Without clear tools for preparation—such as detailed rubrics or examples of how to comprehensively address questions—students struggled to meet expectations and felt unprepared. Additionally, poorly designed problems in past courses often failed to provide students with the opportunity to effectively demonstrate their knowledge or reasoning skills. A lack of explicit efforts to address bias also contributed to wider grading disparities, particularly disadvantageing quieter students. Furthermore, when students did not understand the purpose of the exams or how the skills being assessed connected to their broader educational and career goals, they were less motivated to engage fully with the process.

These collective efforts demonstrate how thoughtful exam design, clear communication, and a commitment to fairness can transform oral assessments from a perceived obstacle into a meaningful and equitable learning experience that prepares students for professional success.

5) Conclusions and Considerations:

The teaching team believes this was a successful intervention. They were able to create, administer, and grade short authentic oral assessments. In these assessments, students were asked to demonstrate authentic engineering practices as described in the literature and in accordance with instructor experience. The teaching team was able to establish strong student buy-in through class discussions, clear rubrics, and ample opportunities for practice. Instructors were able to develop the skills required to keep the oral assessments short, built fluency in the rubric, and took steps to reduce bias. Each of these aspects helped create strong, fair oral assessments. Administering the oral assessments allowed instructors to better understand their students' strengths and needs, and build better relationships in the classroom. Despite their brevity, instructors believed the oral assessments provided a clear picture of student understanding and helped bring nuance to different capabilities. Both students and instructors had a positive experience with the oral assessments; instructors will continue using them in future semesters.

During and after the oral assessments, the teaching team received feedback from colleagues and students. Faculty and administration were broadly enthusiastic about the potential benefit of oral assessment. Because most students experience oral assessment for the first time as part of doctoral qualifying exams or technical interviews, faculty felt this was a good, lower stakes, exposure to oral assessment. Many faculty also noted appreciative remarks from their academic advisees in the course. Colleagues demonstrated hesitancy by warning about the logistical barriers and adverse student experiences they thought oral assessment would bring. In this department, oral assessments are often used as a make-up exam format for written exams to minimize the time of having to write and grade new problems. It is, however, also frequently perceived by students and instructors as a penalty or disincentivization for students to take make-up because oral assessments are intimidating. It is the teaching team's hope that this intervention is a step forward in changing these perceptions.

Students reported an overall positive experience in the oral assessments. While many students experience stress surrounding the assessment, they understood the goals and value of the exams and therefore appreciated the experience. Several students also reported feeling better prepared for technical interviews later in the semester. One student on an academic advisory committee remarked that a common piece of feedback collected from the undergraduate student body is that the students would like to have more oral assessments; this was a step in that direction.

Below are selected considerations: aspects of the orals that the teaching team feels were the most important for successful oral assessments:

- Motivating the exam and being transparent about the teaching teams' goals.
- Providing opportunities for student practice as part of class activities. Any practice engaging in engineering conversations helps students build skills and feel prepared for the oral assessments.
- Conducting mock exams for instructors so that they could practice asking questions and follow-ups, and correctly pacing the exam. This helped create a smooth, fair environment for students during the real exam.

- Conducting a mock exam for students in front of the class where an instructor plays the role of student, so that students can see the types of things the teaching team expects.
- Having a TA take notes during the exam. This was useful for record keeping and sharing useful feedback with students
- Having a clear rubric that the students have access to ahead of time. This helps keep the oral assessments on pace, ensure grading is as fair as possible, and helps create student buy-in.

No intervention is perfect the first time around. In future semesters, the teaching team plans to:

- Have students sign up for slots across 2-3 days (possibly including a lecture time or 1 day a week for 2 weeks) instead of using 7 lab sections across an entire week. This will help condense the testing time for the teaching team and make schedules more manageable.
- Practice with unexpected answers. Having a TA play a struggling student or practicing with someone only tangentially familiar with the material helps instructors learn to adapt in confusing situations and ask meaningful follow-up questions that bring out student strengths.
- Incorporate more discussion with the teaching team into class. Right now, students can ask the teaching team for help while working on in class assignments. In the future, the teaching team plans to incorporate verbal check-ins to further prepare students for the oral assessments.

The teaching team recommends the implementation of short authentic oral assessments in manufacturing (and other engineering subjects) courses. Although instructors may initially struggle with the process of creating, administering, and grading the oral assessments, these are skills that can be built with practice and reflection. It is the teaching team's goal that this document will help curious educators understand what to expect during the implementation of these exams as well as provide resources that instructors can adapt in their own classes. We hope that these efforts and reflections will inspire other curious educators to explore the use of oral assessments, fostering more authentic, engaging, and effective assessment practices in engineering education.

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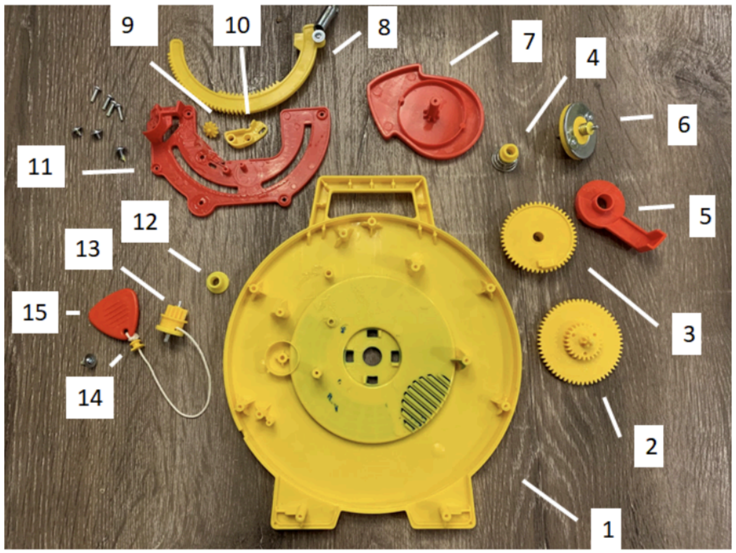
Appendixes:

Appendix A: In Class Problem Examples

Take the See-N-Say apart as completely as you can. Make sure to find all the parts shown below, there may be some nested within others.

a. *(5 minutes)* On the picture below, circle the number of each part you believe was made using injection molding.



(1) Front case
(2) Stacked gear
(3) Protrusion gear
(4) Protrusion gear bearing
(5) Red Lever
(6) Flywheel (Flying Saucer)
(7) Red Arrow
(8) Yellow RipCord Curved Rack
(9) Tiny Pinion Gear
(10) Tiny Pinion Cover (including preload mechanism)
(11) Red Drivetrain Retainer
(12) Boss ring
(13) Cable winder
(14) Cable grommet
(15) Red pull tab

(5 minutes) If you have an injection molding machine with a fixed maximum injection pressure, would a small thick part, or a large thin part be of greater risk for a short-shot defect? Explain.

(5 minutes) Explain your thoughts on the accuracy of this model to predict the injection pressure for the back case, given the assumptions made. Is your result an overestimate or underestimate, and why? Would you want to overestimate or underestimate this? Why are the defects associated with your choice preferable?

(5 minutes) Why do you think the manufacturer decided to put the gates on the side that they did? What compromises did they have to make to do this?

(3) ***(20 min)*** **Heat Transfer**

Assume a thermal diffusivity of $\alpha = 0.1\ mm^2/s$ for thermoplastics. Please write down any assumptions you make (eg. dimensions used). Calculate the cooling time for the following parts. (While you will not be graded on accuracy, we recommend writing down the equation you use and boxing your final answers as a good habit to also use in check-offs and quizzes.)

a. (4 min) Part 16, the back case.

b. (4min) Part 14, the cable grommet.

Appendix B:

	5	4	3	2	1
CRQFS	Student accurately describes the tradeoff between at least two of the five factors (CRQFS) with attention to detail and relevant nuances.	Student accurately describes the tradeoff between at least two of the five factors.	Students can accurately describes the tradeoff between at least two of the five factors (CRQFS) with some help from instructors.	Student struggles to describe tradeoffs between the five factors (CRQFS), but can eventually come to conclusions with support from instructors.	Student is unable to compare two of the five factors (CRQFS) attributes, even with significant help from instructors.
DFM	Student explains the connections between design decisions and manufacturing processes, can clearly weigh tradeoffs, and uses sound engineering judgment to make nuanced and explicit suggestions.	Student explains some connections between design decisions and manufacturing processes, can weigh tradeoffs, and uses some engineering judgment to make reasonable suggestions.	Student explains the connections between design decisions and manufacturing processes, but has difficulty weighing tradeoffs or making suggestions without help from instructors.	Student struggles to explain the connections between design decisions and manufacturing processes and has difficulty weighing tradeoffs. Significant help from instructors is required.	Student is unable to explain connections between design decisions and manufacturing processes and cannot weighing trade offs, even with significant help from instructors.
Processes & Parameters	Student correctly identifies the manufacutring process and influential process parameters, and independently makes context-dependent conclusions about the direction and degree of the effect of modifying interdependent parameters.	Student correctly identifies the manufacturing process and influential process parameters and makes context-dependent conclusions about the direction and degree of the effect of modifying interdependent parameters with help from instructors.	Student is able to correct their process identificaiton and identifies process and influential process parameters, but struggles to make context-dependent conclusions about the direction or degree of the effect of modifying interdependent parameters without significant help from instructors.	Student struggles to identify the process and influential process parameters or make context-dependent conclusions about the direction and degree of effect of modifying interdependent parameters, even with significant help from instructors.	Student is unable to identify influential process parameters or make context-dependent conclusions about the direction or degree of the effect of modifying interdependent parameters, even with significant help from instructors.
Communication	Student communicates clearly, articulating precise concepts with appropriate discipline-specific language to demonstrate understanding. Student may articulate gaps in their understanding if/when they get stuck, but are able to navigate a logical path forward.	Student communicates clearly, articulating concepts with field-specific language to demonstrate understanding. Student may articulate gaps in their understanding if/when they get stuck, but are able to navigate a logical path forward with some help from instructors.	Student articulates concepts with some field-specific language to demonstrate understanding. Student may articulate gaps in their understanding if/when they get stuck, but struggle to navigate a logical path forward, even with help from instructors.	Student articulates concepts with limited understanding. Student may articulate gaps in their understanding if/when they get stuck, but are unable to navigate a logical path forward, even with help from instructors.	Student cannot articulate concepts or demonstrate understanding.

Appendix C:

	5	4	3	2	1
Manufacturing processes	Student **correctly** identifies the manufacturing process, is able to provide **multiple logical** observations/reasons to support their conclusion, and may **articulate how** key features of a manufactured object would change if made another way.	Student **correctly** identifies the manufacturing process, is able to provide **a logical** observation/reason to support their conclusion, and can articulate **some key features** that would change if made another way with **minimal help**.	Student **correctly** identifies the manufacturing process and is able to provide **some relevant observations**/reasons to support their conclusion **with some help.**	Student **struggles to correctly** identify the manufacturing process but is able to provide **limited** observations **with substantial help.**	Student **is unable to** identify the manufacturing process and **struggles** to provide **relevant observations** with substantial help.
Data Interpretation	Student **precisely identifies** characteristics of a normal distribution curve, **connects** those characteristics to the given **context**, and makes relevant and **specific conclusions** from data.	Student **accurately identifies** characteristics of a normal distribution curve, **connects** those characteristics to the given **context**, and makes **relevant conclusions** from data with **minimal help.**	Student **identifies** characteristics of a normal distribution curve with some accuracy and can **connect** those characteristics to the given **context** and make **general conclusions** from data **with help.**	Student **identifies some** characteristics of a normal distribution curve, but requires **significant help** to **connect** those characteristics to the given context and **help to make conclusions** from the data.	Student **is unable to identify** characteristics of the data and **unable apply it in context**. Student is **unable to make relevant conclusions** from the data with help.
Process Variation and Problem solving	Student is able to **logically identify potential** sources of variation **appropriate to the specific context**, may be able to describe the **relative magnitude** of different effects, and can **propose specific solutions** for characterization and mitigation of the source of variation.	Student is able to **identify potential** sources of variation **appropriate to the context**, and can **propose solutions** for characterization and mitigation of the source of variation with **minimal help.**	Student is able to **identify potential** sources of variation and **propose solutions** for characterization and mitigation of the source of variation **with some help.**	Student **struggles to identify** sources of variation and to **propose solutions** for characterization and mitigation of the source of variation **with significant help.**	Student **is unable identify** sources of variation and solutions for characterization and mitigation of the source of variation, **even with help.**
Communication	Student communicates **clearly**, articulating precise concepts with **appropriate field specific** language to demonstrate understanding. Student may articulate gaps in their understanding if/when they get stuck, but are able to **independently** navigate a logical path forward.	Student communicates **clearly**, articulating concepts with field-specific language to demonstrate understanding. Student may articulate gaps in their understanding if/when they get stuck, but are able to navigate a logical path forward **with minimal help** from instructors.	Student articulates concepts with **some** field-specific language to demonstrate understanding. Student may articulate gaps in their understanding if/when they get stuck, but **struggle** to navigate a logical path forward, **even with help** from instructors.	Student articulates concepts with **limited understanding**. Student may articulate gaps in their understanding if/when they get stuck, but are **unable** to navigate a logical path forward, even with help from instructors.	Student **cannot** articulate concepts or demonstrate understanding.